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FOURTH ANNUAL MAINTENANCE SYMPOSIUM

THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM

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December 3-5, 1968

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

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FOREWORD

A WORD ABOUT THE FOURTH ANNUAL FAA MAINTENANCE SYMPOSIUM

The Man In The Maintenance Reliability System is the key to aviation maintenance safety.

Are we keeping up with technology or have gaps developed between the advanced design and construction techniques and the man who performs the tasks that keep the aircraft in an airworthy condition?

Experts in their respective fields gathered at the fourth annual FAA maintenance symposium, at the Skirvin Hotel, Oklahoma City, Oklahoma, on December 3, 4, and 5, 1968, to discuss The Man In The Maintenance Reliability System. This publication is a compilation of the papers presented at that symposium. The papers indicate what is being done to keep the man in the maintenance reliability system current in his vocation and also forecast future trends and needs.

Papers presented at this fourth annual FAA maintenance symposium represented the opinions, ideas, practices and proposals of each individual panelist who in turn reflected the policies and practices of his respective company. The speakers have granted permission to the FAA to reprint and publish their papers as presented at the 1968 maintenance symposium.

A list of the symposium attendees will be found in the back of this volume.

PROLOGUE

Welcome to the 1968 Maintenance Symposium, "The Man In The Maintenance Reliability System - A Positive View." This event, which annually brings together the top people nationally and internationally in aviation maintenance, began fairly modestly in 1965 to exchange information about maintenance reliability. It has been successful not only in terms of attendance and participation but also in the quality of the information exchanged. Our first symposium featured the maintainability and reliability of aircraft propulsion systems. The second, in 1966, dealt with aircraft structures. Last year, aircraft systems were emphasized. This year, we will highlight the man in the system.

Each of the papers presented during this symposium will deal with some aspect of maintenance reliability as it affects or is affected by the man in the system.

I will not attempt to compete during the prologue with the professionals who are presenting the papers, but I would like to say a few words about why we are here.

First, let us not forget the man. We are here to talk about maintenance reliability but, more importantly, about the man in the system. If we stray too far afield, we will not have accomplished our purpose. It would be well for us to remember that "maintenance" has its roots in two Latin words (manu tenere) that mean "to know for certain" but which, literally translated, mean "to hold in the hand." Now, I do not see how we can come more directly to the issues than to discuss the hands in which the reliability system is held.

Secondly, where does the man in <u>your</u> maintenance reliability system fit in on <u>your</u> planning? Where does he come from, how do you select him, how do you train him, how do you make the best use of him, both from your viewpoint and his? We shall learn, I think, that he knows or can be made to know, what is to be done and how to do it, -- but does he know why he is doing?

Presented by Harry A. Turnpaugh, Chief, Maintenance Division, Flight Standards Service, Federal Aviation Administration, Department of Transportation, at the FAA 1968 Maintenance Symposium, Oklahoma City, Oklahoma, December 3-5, 1968.

Does he understand what *your* reliability system needs to accomplish to be successful? We must remember that no matter what procedures, resources, or standards are prescribed to make a maintenance reliability system function, its ultimate outcome will depend upon whether the people who perform the necessary actions and make the judgments "get the word."

Since the early days of large scale reliability programs, a lot of thought, action, and resources have been expended to convince management and planning levels in industry and government that maintenance reliability systems not only make good business sense but produce the desired results in terms of safety. In a very real sense, management has sold reliability concepts to management.

But, conversely, not much has been done to help the men who "hold the reliability systems in their hands" to understand what sort of thing they are dealing with and what it is producing.

It is true that time and exposure are great teachers, but many of the every-day decisions and judgments that must be made down at the working level depend upon a knowledge of what is intended to be accomplished by the whole system. My message is this — "When you are talking maintenance reliability, remember the man." It could mean the difference between success and failure of the program or even between safety and disaster.

As you have noticed, the subtitle of this symposium is "A Positive View." Let me speak a few moments about a positive effort that is intended to offer some recognition to the men who have contributed so much to aircraft maintenance and reliability. Each year since 1963, FAA and industry have engaged in a cooperative venture to provide some recognition to the aviation mechanic through the Annual Aviation Mechanic Safety Awards Program.

The purpose of the awards program is to give recognition to aviation mechanics who are making outstanding contributions to aviation safety by maintenance practices.

It enables the public to recognize the importance of the mechanic in air safety and serves to focus the attention of the mechanic himself upon his vital safety role.

Nominations are accepted from mechanics themselves or from other persons who know of original and significant contributions to air safety by maintenance practices. Entries are judged in three categories: improvements or airframes, engines, or components; improvements to maintenance or inspection procedures; and outstanding demonstration of professionalism in carrying out a mechanic's duties.

State awards are made to general aviation winners who are, in turn eligible to compete for regional awards. Regional awards are made to one air carrier mechanic and one general aviation mechanic in each of the eight FAA regions. Regional winners compete for the national awards. National awards are made to one general aviation mechanic and one air carrier mechanic.

Each winner is given a certificate or plaque, and in the case of the national winners, an especially created medallion and other more-tangible rewards from various industry associations and companies.

The Aviation Mechanic Safety Awards Program can be judged to be a success in every way. Through it, we have been able to give some much-deserved recognition to a few of the outstanding contributions being made by aviation mechanics. Your support of the program is invited. If you know of original and significant contributions to aviation safety by maintenance practices, make a nomination. If you would like to participate in other ways, let us know.

While I have spoken primarily about the mechanics in the system, this symposium is not limited to him. For a system to be successful all men in the system must be considered. The man, the supervisor, the teacher, the one who prepares manuals of instruction, the computer man, the parts man, the planner, etc., — they are all part of the system and they are all necessary.

I would like to thank all the people in the industry who have offered to present papers during the limited time available. The most difficult task during the planning of each year's symposium is the selection of papers from the many that are offered. We have made a sincere effort to select papers that will offer you a well-balanced agenda and be representative of those in attendance.

I will now call upon Mr. Robert Burbick, who heads the Regulations and Directives Branch of the Maintenance Division, to give us a brief over-view of the complex that makes up the regulatory portion of the maintenance reliability system. Perhaps we can use his remarks as a sort of launching platform from which we will proceed directly with the business at hand.

Thank you for coming. We look forward to exchanging views and information with you for the next 2½ days.

AIRMAN CERTIFICATION

The major missions of the FAA are:

*Promote safety

*Insure efficient utilization of airspace

*Promote air commerce and civil aviation at home and aboard

*Fulfill national defense requirements

*Administer programs efficiently and economically

Our sponsoring this symposium falls mainly under the first mission; i.e., Promote safety. We trust all of you will leave our fourth annual maintenance symposium motivated by the various presentations and discussions — that you will have a better understanding of the many roles played by the numerous men and women in the reliability system and why we must continue to work together for continued growth and safer air transportation.

The Man In The Maintenance Reliability System is the catalyst in all of our FAA safety programs. By no means do we wish to ignore the ladies.

They are an integral part of the total system that makes our U.S. Civil Aviation and Aerospace industry the largest and most successful in the world.

> There is an old aviation axiom that goes like this: "Aviation is not inherently dangerous — but to an even greater extent than the sea, it is terribly unforgiving of any carelessness, incapacity, or neglect. Safety of aircraft is delegated through various levels but in the final analysis, it is the mechanic working on the aircraft who has this responsibility."

The efforts of many of these artisans, the engineers, pilots, and managers on the reliability team go unrecognized. As the various panels make their presentations, one should realize that while we in regulation business of FAA are inclined to point our rules at those persons or agencies holding FAA certificates — we should not lose sight of the many thousands of non-certificated persons who make it possible for our industry and safety programs to be the success that they are.

Presented by Robert A. Burbick, Head, Regulations and Directives Branch, Maintenance Division, Flight Standards Service, Federal Aviation Administration, Department of Transportation.

At this time -- the start of our symposium -- we need some sort of a bench mark from which we can measure the scope of the system, especially from the manpower and dollar point of view.

First, let's identify the number of persons holding FAA certificates. --

Our latest, records (1966) indicate there are over 689 thousand active certificated airmen. Of this number approximately 20% are certificated mechanics.

Pilots and flight engineers account for an additional 70%.

Control tower operators, dispatchers, ground inspectors parachute riggers and others make up the remaining 10%.

The aerospace industry is the nation's largest manufacturing employer; last year their payroll alone totaled 12.4 billion dollars or 9.2% of the total U.S. manufacturing payroll.

Aircraft and engine manufacturers employed 367,000 production workers in 1967. The aerospace industry employed 371,900 engineers and scientists. Other associated jobs employed 100,000 men and women. The missile and space industry employed an additional 600,000. This adds up to over 2 million persons.

The U.S. civil aircraft fleet numbers approximately 142,000. More than 72% of the 3,541 aircraft operated in the world's civil airlines were designed and built in the U.S. to our standards.

Last year, general aviation manufacturers produced 13,577 aircraft valued at over 359 million dollars. Major manufacturers of aeronautical products report a backlog of 20.6 billion dollars.

We, in FAA, consider all of these persons and facilities play a major role in the total maintenance reliability system. Once the aircraft is designed, built and marketed the primary responsibility for its safe operation rests upon the owner and the certificated airmen and maintenance facilities.

Time will not permit a discussion of all of their activities.

However, we do want to spotlight the certificated mechanic because he is the airman identified in the Federal Aviation Act of 1958 as the individual who is directly in charge of the inspection, maintenance, overhauling, or repair of aircraft, aircraft engines, propellers, or appliances.

Further, Section 610(a)(2) of the Act states —

> "It shall be unlawful — for any person to serve in any capacity as an airman in connection with any civil aircraft, aircraft engine, propeller, or appliance used or intended for use in air commerce without an airman certificate authorizing him to serve in such capacity, or in violation of any term, condition, or limitation thereof, or in violation of any order, rule, or regulation issued under this title; (3)"

The first Federal Regulation involving the issuance of mechanic license was contained in Section 72 of the old air commerce regulation effective December 31, 1926. It provided for an engine mechanic license and an airplane mechanic license. The first license #1 was issued to Frank G. Gardner of College Park, Md on July 1, 1927.

After adoption of the Civil Aero Act of 1938, Part 24 was implemented. It provided for the issuance of an aircraft mechanic rating and an aircraft engine mechanic rating.

Amendment 109, effective May 16, 1941, provided for the issuance of a factory mechanic rating.

In the fall of 1944, the Civil Aeronautics Board proposed to amend Part 24 to provide for additional mechanic ratings and a higher degree of specialization. This proposal was not adopted and since that time, there have been numerous efforts to recognize in the regulations that industry has developed a highly specialized cadre of maintenance personnel whose utilization is somewhat restricted because of the airmen requirements of the Act.

Moreover, since the end of World War II, we periodically receive petitions to amend the rules to provide for further specialization. The latest involves such areas as avionics, helicopters, jet engines, and certain nondestructive test operations.

While we are sure these petitioners are sincere, they have not provided a very strong argument or compelling safety reason why it is in the public interest to expand the maintenance airman certification system.

Actually, we have a very effective method of recognizing specialized mechanics skills. This is the repairman certificate. It is used to rate personnel in specialized areas where both skill and facilities are needed and personnel do not normally meet the full requirements for A&P certificate.

Efficient and effective utilization of technical manpower is a must for the future; therefore, we must continue to search for the answers or solutions to the technical manpower shortage in certain areas of civil aircraft maintenance.

To gain a broader understanding and industry appreciation for the problems facing maintenance airmen, the FAA in 1961 was instrumental in causing the California Aviation Education Association to undertake a study in California to determine the industry requirements for airframe and powerplant mechanics.

This activity subsequently resulted in a much more comprehensive study known as "A National Study of the Aviation Mechanics Occupation." This study will be discussed by Dr. Allen on Panel IV Wednesday.

While there has been no significant change in the mechanic certificate requirement, there have been major changes in other FAA rules and operating procedures. Today, repair stations and mechanics with inspection authorizations keep the general aviation fleet operating on a day-to-day basis.

They return the majority of major maintenance work to service. Various FAA designees perform a large portion of the examinations and tests required by the airmen certification regulations. Repairmen perform very vital specialized safety functions at repair station and air carrier maintenance bases.

While these airmen programs do generate problems, they are without question an essential part of our safety program and provide a balance between safety and taxpayer burden. It's hard to knock success and there is little question about the success of the present system. Even so, there is always room for improvement.

The various presentations may prompt specific questions involving our maintenance and airmen certification rules, procedures or future plans. We invite you to make a note of the question and present it to the FAA Maintenance Division Branch Chiefs at the Thursday morning question and answer session.

We hope the symposium and its free exchange of ideas will provide us with additional insights into the proper training and certification and utilization of maintenance airmen. That in some way, it will make the maintenance reliability system better and that all of us who have had a part in the action will leave Oklahoma City and this symposium motivated to do a better job for safety and our employer.

HUMAN ENGINEERING/MAINTAINABILITY INTERFACE ON THE C-5A

INTRODUCTION

AS A PART OF ITS CONTINUING PROGRAM OF AIRLIFT DEVELOPMENT ACTIVITIES, LOCKHEED-GEORGIA COMPANY HAS DEVOTED MANY YEARS TO DESIGN STUDIES IN THE CATEGORY OF HEAVY LOGISTICS TRANSPORTS.

IN 1964 AND 1965, UNDER UNITED STATES AIR FORCE CONTRACT, THE COMPANY REFINED AND FURTHER DEFINED ITS DESIGN CONCEPTS IN COOPERATION WITH THE MILITARY . . . AN EFFORT WHICH RESULTED IN AN OCTOBER 1965 CONTRACT AWARD FOR PROCUREMENT OF THE C-5A. THE UNIQUE TOTAL PACKAGE CONCEPT ASSIGNS RESPONSIBILITY FOR ENGINEERING, DESIGN, DEVELOPMENT, TESTING, AIRCRAFT PRODUCTION, SPARES AND TOTAL SYSTEM PERFORMANCE TO THE PRIME CONTRACTOR.

DESIGNATED THE C-5A BY THE U. S. AIR FORCE, THE AIRPLANE IS NOW BEING MANUFACTURED. CONTRIBUTING BIG, NEW CAPACITY, LARGE-SYSTEM ECONOMY, AND BOLD PERFORMANCE TO U. S. AIRLIFT CAPABILITY, IT MAY WELL REVOLUTIONIZE THE CONCEPT OF FLEXIBLE RESPONSE AND RAPID DEPLOYMENT OF U. S. MILITARY FORCES AROUND THE WORLD. THE LOCKHEED-GEORGIA COMPANY, A DIVISION OF THE LOCKHEED AIRCRAFT CORPORATION, IS PROUD TO BE THE INDUSTRIAL MEMBER OF THE TEAM WHICH IS DEVELOPING THE UNITED STATES AIR FORCE C-5A. PARTICULAR EMPHASIS HAS BEEN GIVEN TO THE C-5A IN THE AREA OF MAINTAINABILITY.

SURVEYS CONDUCTED BY THE AIR FORCE SEVERAL YEARS AGO IN CONJUNCTION WITH THE DEVELOPMENT OF A GUIDE TO MAINTAINABILITY ARE QUITE REVEALING. THE MORE SIGNIFICANT FINDINGS OF THE SURVEYS INDICATED THAT, ALTHOUGH MAINTAINABILITY IS WIDELY DISCUSSED AND THE UNDERLYING CONCEPTS ARE WIDELY ACCEPTED.

Paper prepared by William H. McAbee and Thomas [illegible] Hall, Human Factors Engineer, Specialists, Personnel Subsystems Engineering Dept., Lockheed-Georgia Co., a Division of Lockheed Aircraft Corp., Marietta, Ga. Paper presented by William H. McAbee at the FAA Maintenance Symposium, Oklahoma City, Dec. 3-5, 1968.

THERE IS ROOM FOR IMPROVEMENT. THE FINDINGS ALSO SHOWED THAT A BASIC PROBLEM OF MAINTAINABILITY, AS IT IS CONCEIVED, UNDERSTOOD AND PRACTICED TODAY, IS THE LACK OF COMMON AGREEMENT IN THE FOLLOWING:

(1) THE NATURE, SOURCES, AND CONSEQUENCES OF THE PROBLEM, I.E., WHAT REALLY IS THE PROBLEM OF MAINTAINABILITY?

(2) A METHOD FOR MEASURING MAINTAINABILITY IN ORDER TO EVALUATE AND DIRECT EFFORTS INTENDED TO IMPROVE MAINTAINABILITY.

(3) A CONSOLIDATED SET OF BASIC DESIGN REQUIREMENTS THAT IS DIRECTLY RELATED TO THE EXPLANATION AND THE METHOD OF MEASUREMENT.

EACH OF THE THREE PROBLEMS, ACCORDING TO THE RESEARCHED LITERATURE, ARE THE PROBLEMS WITH WHICH MAINTAINABILITY SHOULD BE CONCERNED.

THE INFORMATION IN THE NEXT SECTION PRESENTS A BRIEF VIEW OF THE MORE BASIC MAINTAINABILITY PROBLEMS. ALTHOUGH MOST OF THE ITEMS HERE HAVE BEEN DISCUSSED IN OTHER SOURCES, THE PRESENT EFFORT IS SIMPLY TO COLLECT THEM IN A GROUP TO PROVIDE A "BIRD'S-EYE VIEW" WHICH DEMONSTRATES THE NEED FOR A HUMAN ENGINEERING/MAINTAINABILITY INTERFACE.

SCOPE OF THE PROBLEM

THE EMPHASIS UPON MAINTAINABILITY HAS ARISEN IN RECOGNITION OF THE TREMENDOUS COSTS OF FAILURES AND MAINTENANCE TO THE AVIATION INDUSTRY, MANUFACTURERS, ARMED SERVICES, AND OTHERS, AND THE ALARMING RATES AT WHICH THESE COSTS ARE INCREASING. MANY OF THESE "COSTS" ARE NOT READILY DEFINABLE IN TERMS OF DOLLARS AND CENTS; THEY SHOW UP AS LIVES LOST OR FAILED MISSIONS. IN GENERAL, HOWEVER, THE MOST ACCEPTED INDICATORS OF THE PROBLEM SEEM TO BE THE DOLLAR-COST, TIME, AND MANPOWER REQUIRED TO FULFILL MAINTENANCE REQUIREMENTS. A FEW ARMED SERVICES FIGURES WILL SERVE TO ILLUSTRATE THE MAGNITUDE OF THE PROBLEM.

(1) ONE-THIRD OF ALL AIR FORCE OPERATING COST IS FOR MAINTENANCE.

(2) ONE-THIRD OF ALL AIR FORCE PERSONNEL ARE ENGAGED IN MAINTENANCE, THOUGH A LARGE PORTION OF THE MAINTENANCE IS DONE BY CONTRACT.

(3) THE DEPARTMENT OF DEFENSE ANNUALLY PROGRAMS APPROXIMATELY 7 BILLION DOLLARS FOR MAINTENANCE OF EXISTING EQUIPMENT.

(4) MAINTENANCE COSTS, OVER THE PERIOD OF EXISTENCE (5-10 YEARS) OF A GIVEN PIECE OF EQUIPMENT OFTEN RANGE FROM 10 TO 100 TIMES THE ORIGINAL PROCUREMENT COST OF THE EQUIPMENT.

(5) "UP TO 85% OF THE PROCUREMENT COST OF NEW SYSTEMS IS FOR MAINTENANCE RELATED FEATURES AND GROUND SUPPORT EQUIPMENT."

(6) THE MAINTENANCE MAN-HOUR REQUIREMENT HAS STEADILY INCREASED FROM 20 MAINTENANCE HOURS PER FLYING HOUR FOR THE B-17 TO 120 HOURS FOR THE B-52. WITH THE EXCEPTION OF TRANSPORTS, SIMILAR COMPARISONS ARE POSSIBLE FOR MOST OTHER TYPES OF EQUIPMENT.

FAILURES IN THEMSELVES EXACT HEAVY PENALTIES. THEY ENDANGER LIVES, JEOPARDIZE THE SUCCESS OF MILITARY MISSIONS, AND CAUSE THE DESTRUCTION OF COSTLY EQUIPMENTS. OFTEN THEY ARE RESPONSIBLE FOR LIMITING THE AVAILABILITY OF MEN AND EQUIPMENT FOR STRATEGIC OR COMBAT USE.

THE MAINTENANCE REQUIRED TO PREVENT OR CORRECT FAILURES EXACTS DRASTIC ECONOMIC PENALTIES THROUGH HEAVY UPKEEP COSTS. EXAMPLES:

(1) A HANDICAP TO PRODUCTION BECAUSE REPLACEMENT PARTS AND EQUIPMENT HAVE TO BE PRODUCED.

(2) A STRAIN ON SUPPLY, STORAGE, AND SHIPPING FACILITIES.

(3) A HEAVY PERSONNEL BURDEN TO STAFF THE SUPPLY AND MAINTENANCE SYSTEM.

(4) A CONSTRAINT ON RESEARCH AND DEVELOPMENT FUNDS USED TO PROVIDE MAINTENANCE EQUIPMENT, ACCESSORIES, AND DOCUMENTS, AS PART OF NEW WEAPON SYSTEMS.

AVERAGE AIR FORCE MAINTENANCE MAN

A MAJOR PROBLEM IN DEFINING THE DOMAIN AND OBJECTIVES OF MAINTAINABILITY IS: WHAT PERSONNEL FACTORS SHOULD BE CONSIDERED IN DESIGN FOR MAINTAINABILITY?

THE REALM OF "PERSONNEL FACTORS" IS VIRTUALLY INEXHAUSTIBLE. AS GUIDANCE TO THE SELECTION OF FACTORS AND DATA WHICH ARE APPLICABLE TO ANY GIVEN DECISION, IT IS RECOMMENDED THAT DESIGN FOR MAINTAINABILITY:

(1) CONSIDER ONLY THOSE FACTORS AND DATA WHICH - -

ARE DIRECTLY EMPLOYABLE BY THE DESIGNER OR MAINTAINABILITY ENGINEER,

HAVE A DIRECT AND MEASURABLE RELATIONSHIP OR A DEMONSTRABLE SIGNIFICANCE, TO THE FEATURES AND CHARACTERISTICS OF DESIGN, AND

ARE SPECIFIABLE AS DESIGN LIMITS OR REQUIREMENTS.

(2) ALLOW THE REQUIRED MAINTENANCE TO BE PERFORMED BY ANY OR ALL OF THOSE MAINTENANCE MEN BETWEEN THE 5^{th} AND 95^{th} PERCENTILES ON THE RELEVANT PARAMETERS.

(3) BE BASED UPON THE ASSUMPTION THAT THE EQUIPMENT WILL BE MAINTAINED BY THE AVERAGE AIR FORCE MAINTENANCE MAN, AS DESCRIBED BELOW.

THE SKILLS THAT ARE AVAILABLE AT ORGANIZATIONAL AND FIELD LEVELS ARE: AN AVERAGE AIRMAN WHO IS A HIGH SCHOOL GRADUATE, HAS 4 YEARS OF MILITARY SERVICE, HAS COMPLETED ONE BASIC TECHNICAL SCHOOL AND ONE ADVANCED TECHNICAL SCHOOL OF APPROXIMATELY 3 MONTHS DURATION.

THE AIR FORCE MAINTENANCE MAN OFFERS AN ENORMOUS RANGE OF POTENTIALITIES AND CAPABILITIES. THE REALIZATION AND UTILIZATION OF THESE DEPENDS EXTENSIVELY UPON THE KNOWLEDGEABLE CARE THAT GOES INTO EQUIPMENT DESIGN AND THE SPECIFICATION OF MAINTENANCE ROUTINES, PROCEDURES, SCHEDULES, JOB AIDS, AND SUPPORT EQUIPMENT. IN A VERY REAL SENSE, THE ABILITY OF THE MAINTENANCE MAN IS A FUNCTION OF THE DESIGN AND SUPPORT CONSIDERATIONS THAT CONSTITUTE THE ENVIRONMENT IN WHICH HE MUST WORK.

OPERATIONAL PROBLEMS AND PRACTICES

COMMON DESIGN DEFICIENCIES

SOME OF THE MORE COMMONLY MENTIONED DESIGN DEFICIENCIES THAT CONTRIBUTE TO THE TECHNICIAN'S PROBLEMS AS REPORTED BY MILITARY TECHNICIANS THEMSELVES ARE:

(1) FASTENERS - "FASTENERS CONTINUE TO COME IN A VAST VARIETY OF TYPES, SIZES, AND LENGTHS, AND DESIGNERS INTERMIX THEM UNNECESSARILY."

(2) CONNECTORS - "THERE ARE AN EXCESSIVE NUMBER OF PLUG TYPES AND THEY BECOME LADEN WITH FOREIGN MATTER AND MOISTURE."

(3) ACCESSIBILITY - "ACCESS PROVISIONS ARE A CONTINUED PROBLEM. APPARENTLY THE CONTRACTORS BUILD THE FRAME FIRST, THEN PROCEED TO CRAM STUFF INTO IT."

(4) SERVICING - "A LOT OF TIME IS WASTED BY UNNECESSARY MOTIONS IN SERVICING."

(5) CALIBRATION - "CALIBRATION IS A REAL PROBLEM BECAUSE THERE ARE FEW REAL STANDARDS, AND STANDARDS SHIFT. TOLERANCES PLACED ON EQUIPMENT IN MANUFACTURE ARE OFTEN INTOLERABLE IN THE FIELD."

(6) INTERCHANGEABILITY - "EVEN THE EQUIPMENT BUILT TO THE SAME MILITARY SPECIFICATIONS BY DIFFERENT CONTRACTORS DOESN'T CONTAIN INTERCHANGEABLE PARTS. THIS MAKES CANNIBALIZING IMPRACTICAL."

(7) TOOLS - "TOOLS ARE NOT SUFFICIENTLY STANDARDIZED AND TOOL REQUIREMENTS ARE NOT SUFFICIENTLY COORDINATED."

POTENTIAL MAINTENANCE DESIGN DEFICIENCIES

THIRTY-NINE (39) POTENTIAL MAINTENANCE DESIGN DEFICIENCIES WERE IDENTIFIED DURING CATEGORY I TESTING ON A CENTURY SERIES NUMBERED FIGHTER AIRCRAFT. THESE DEFICIENCIES WERE SUBSEQUENTLY CONFIRMED AND COMMENTED UPON BY AIR FORCE, NAVY, AND CONTRACTOR PERSONNEL.

THIRTY-TWO (32) OF THE THIRTY-NINE (39) POTENTIAL MAINTENANCE DESIGN DEFICIENCIES WERE FOUND TO BE IN THE AREAS OF ACCESSIBILITY, SERVICING, AND SAFETY. THESE FINDINGS ARE CONSISTENT WITH THE AIR FORCE SURVEY REPORTS DISCUSSED EARLIER IN THIS PAPER AND FURNISH USEFUL GUIDELINES OF COMMON DESIGN DEFICIENCIES THAT SHOULD BE AVOIDED IN ANY MAJOR AIRCRAFT DEVELOPMENT PROGRAM.

C-5A HUMAN ENGINEERING/MAINTAINABILITY INTERFACE

ORGANIZATION

LOCKHEED IS RESPONSIBLE TO THE PROCURING AGENCY FOR INSURING THAT ADEQUATE HUMAN ENGINEERING IS ACCOMPLISHED (A) DURING SYSTEM DESIGN TO ACHIEVE AN EFFECTIVE ASSIGNMENT OF SYSTEM FUNCTIONS TO MAN AND MACHINE COMBINATIONS THEREOF AND (B) THROUGHOUT THE DESIGN AND DEVELOPMENT OF SYSTEM HARDWARE TO OBTAIN EFFECTIVE AND SAFE MAN-MACHINE INTERACTIONS AND COMPATIBILITY.

BASED UPON PAST EXPERIENCE WITH THE C-130 AND C-141 PROGRAMS, AIR FORCE SURVEYS, AND KNOWLEDGE OF POTENTIAL DESIGN DEFICIENCIES, ORGANIZATIONS AND WORKING PROCEDURES WERE ESTABLISHED ON THE C-5A PROGRAM TO ENHANCE MAINTAINABILITY. THE ORGANIZATIONS WHICH EVOLVED (HUMAN ENGINEERING AND MAINTAINABILITY) ARE DIRECTED BY QUALIFIED LEADERS WHO IN TURN REPORT TO CENTRAL LEADERSHIP IN THE PERSON OF A DIVISION LEVEL ENGINEER.

PROCEDURES

THE LOCKHEED HUMAN ENGINEERING SECTION, PERSONNEL SUBSYSTEMS ENGINEERING DEPARTMENT APPLIES BASIC KNOWLEDGE OF MAN'S UNIQUE CAPABILITIES AND LIMITATIONS TO EQUIPMENT DESIGN BY:

(1) A HUMAN ENGINEERING JOB PACKAGE SIGN-OFF PROCEDURE.

(2) PARTICIPATING IN PRELIMINARY DESIGN REVIEWS.

(3) PARTICIPATING IN CRITICAL DESIGN REVIEWS.

(4) PARTICIPATING IN TOOL TRIES.

(5) PARTICIPATING IN COMPATIBILITY TESTS.

(6) RECEIVING PSTE FEED-BACK.

(7) EXTENSIVE USE OF FULL-SCALE SOFT MOCK-UPS DEVELOPED TO TEST POTENTIAL PROBLEMS OF ACCESSIBILITY, EASE OF MAINTENANCE, AND SAFETY BEFORE THE DESIGN IS FROZEN.

(8) ORGANIZING AND STAFFING ITS ORGANIZATION TOWARD THE GOAL OF INTEGRATING HUMAN ENGINEERING/MAINTAINABILITY'S CONSIDERATION THROUGHOUT THE DEVELOPMENT AND TEST CYCLE OF THE SYSTEM.

(9) CONDUCTING DETAILED TASK ANALYSES ON MAINTENANCE FUNCTIONS AND SELECTED DESIGN PROBLEMS OF THE C-5A AND ITS SUPPORTING SUBSYSTEM.

(10) INTERACTION WITH AIR FORCE'S HUMAN FACTORS PERSONNEL.

THESE FACTORS RECEIVE SPECIAL CONSIDERATION SO THAT SERVICE AND MAINTENANCE FUNCTIONS MAY BE EXECUTED IN THE EASIEST MANNER IN ORDER TO CONTRIBUTE TO OPERATIONAL AVAILABILITY AND OVERALL COST EFFECTIVENESS.

TEN (10) "REAL WORLD" EXAMPLES WHICH ARE REPRESENTATIVE OF THE C-5A HUMAN ENGINEERING/MAINTAINABILITY INTERFACE FOLLOW.

TIRE INFLATION SYSTEM

A TURBINE DRIVEN COMPRESSOR, LOCATED BETWEEN THE RIGHT MAIN FORWARD AND AFT WHEEL WELLS OF THE C-5A, PROVIDES LOW PRESSURE AIR FOR LANDING GEAR TIRE INFLATION. HUMAN ENGINEERING EVALUATED THE PERSONNEL NOISE HAZARD GENERATED BY THIS TURBINE.

SLIDE 1 - PREDICTED SOUND PRESSURE LEVELS

THIS FIGURE SHOWS THE PREDICTED SOUND PRESSURE LEVELS IN AND ABOUT THE RIGHT MAIN WHEEL WELLS. IT CAN BE SEEN THAT, EVEN WHEN USING EAR MUFFS AND PLUGS, PERSONNEL WORKING IN THE AFT WELL COULD BE EXPOSED TO AS MUCH AS 120 DB. EXPOSURE TO STEADY NOISE OF THIS LEVEL USUALLY LEADS TO A SENSATION OF DISCOMFORT IN THE EAR AFTER A FEW SECONDS. DURING EXPOSURE TO STEADY SOUND FIELDS WITH PRESSURE LEVELS OF 150 DB OR HIGHER, UNDESIRABLE NON-AUDITORY EFFECTS ARE EXPERIENCED REGARDLESS OF THE AMOUNT OF EAR PROTECTION USED. THESE EFFECTS RANGE FROM DISCONCERTING BODY VIBRATIONS TO DISORIENTATION AND NAUSEA AND ALWAYS INCLUDE EXCESSIVE FATIGUE FOLLOWING EXPOSURE.

THE INFLATION PROCESS REQUIRES APPROXIMATELY 14 MINUTES TO BRING ALL WHEELS IN THE RIGHT AFT WELL UP TO THE REQUIRED 120 PSIG. DURING THIS TIME THE MAINTENANCE MAN MUST CONSTANTLY MONITOR THE SYSTEM PRESSURE GAUGE AND MAINTAIN AIR FLOW CONTROL BY MEANS OF A "DEAD MAN" SWITCH.

IN ORDER TO REMOVE THE MAINTENANCE MAN FROM THIS HAZARDOUS ENVIRONMENT, THE GAUGE AND CONTROL WERE PLACED SEQUENTIALLY IN THE HOSE LINE AND THE HOSE LINE LENGTHENED TO PERMIT CONTROL FROM OUTSIDE THE WHEEL WELL AREA. SINCE THE HOSE LINE IS ON-BOARD EQUIPMENT, THUS CONTRIBUTING TO AIRCRAFT

WEIGHT, ITS LENGTH HAD TO BE TRADED OFF AGAINST THE SOUND ATTENUATION ACHIEVED. IT WAS DECIDED TO LIMIT LINE LENGTH TO THAT POINT AT WHICH, WITH THE USE OF EAR MUFFS, MAINTENANCE PERSONNEL WOULD BE EXPOSED TO NO MORE THAN 85 DB, THIS BEING THE SOUND PRESSURE LEVEL AT WHICH PERSONNEL CAN WORK CONTINUOUSLY WITH NO DANGER OF RESULTANT HEARING LOSS.

ENGINE FIRE EXTINGUISHER BOTTLES LOCATION

A HUMAN ENGINEERING EVALUATION WAS PERFORMED TO DETERMINE IF THE ENGINE FIRE EXTINGUISHER BOTTLES LOCATED IN PYLONS NO. 2 AND NO. 3 COULD BE REMOVED AND REPLACED WITHOUT UNDUE DIFFICULTY.

SLIDE 2 - FIRE EXTINGUISHER BOTTLES

AS CAN BE SEEN IN THESE PICTURES, THE PROXIMITY OF ADJACENT EQUIPMENT COUPLED WITH WORKSPACE LIMITATIONS INHERENT IN THE PYLON CREATED A HIGHLY INACCESSIBLE LOCATION FOR THE BOTTLES. ADDITIONALLY, IT WAS DISCOVERED DURING THIS EVALUATION THAT THE PRESSURE GAUGE ON ONE OF THE BOTTLES COULD NOT BE READ BECAUSE OF TUBING ROUTED ACROSS THE FACE OF THE GAUGE. HUMAN ENGINEERING AND MAINTAINABILITY ENGINEERS ENGAGED IN A JOINT EFFORT TO FIND A MORE SUITABLE LOCATION FOR THE BOTTLES - - PREFERABLY ONE THAT COULD BE REACHED FROM OUTSIDE THE PYLON.

UTILIZING A MOCK-UP OF THE DUAL BOTTLE INSTALLATION, A SUITABLE LOCATION WAS FOUND ON THE AFT SIDE OF THE FORWARD PYLON BULKHEAD.

SLIDE 3 - RECOMMENDED FIRE BOTTLES LOCATION

AS SHOWN IN THE SECOND PICTURE, THIS LOCATION IS ADJACENT TO THE PYLON ENTRY DOOR AFFORDING EXCELLENT ACCESS TO THE BOTTLES AND THEIR RESPECTIVE PRESSURE GAUGES.

RUDDER REMOVAL AND REPLACEMENT

THE UNUSUAL HEIGHT OF THE C-5'S EMPENNAGE RESULTED IN A REQUIREMENT FOR SPECIAL AGE IN THE REMOVAL AND REPLACEMENT OF THE RUDDERS. SUCH A PIECE OF EQUIPMENT WAS COMMERCIALLY AVAILABLE; HOWEVER, IT WAS NOT KNOWN WHETHER AN OPERATOR COULD SUCCESSFULLY EXECUTE THE PRECISE MANEUVERS REQUIRED TO MATE THE RUDDER TO THE VERTICAL STABILIZER. IN THE EXPLORATORY STAGE, A DEMONSTRATION OF THE MATING OPERATION WAS PLANNED FOR SHIP NO. [illegible]. BECAUSE OF THE APPARENT HIGH RISK OF DAMAGE TO THE AIRCRAFT'S STABILIZER, THE TRIAL OPERATION WAS NOT ACCOMPLISHED. HUMAN ENGINEERING PERSONNEL CONSTRUCTED A SOFT MOCK-UP OF THE ESSENTIAL MATING POINTS AND POTENTIAL AREAS OF CONTACT ON THE UPPER VERTICAL STABILIZER.

SLIDE 4 AND 5 - MATING OPERATION

USING A PRODUCTION RUDDER AND THE SOFT MOCK-UP, THE MATING OPERATION WAS DEMONSTRATED SEVERAL TIMES WITH NO INCIDENTS WHICH WOULD HAVE RESULTED IN STABILIZER OR RUDDER DAMAGE.

THE DEMONSTRATION DID BRING TO LIGHT SEVERAL HUMAN ENGINEERING DEFICIENCIES IN THE CONTROL SYSTEM OF THE AGE ITEM. CORRECTIVE RECOMMENDATIONS WERE ACCEPTED BY THE VENDOR AND INCORPORATED INTO HIS DESIGN.

WING ACCESS

THE NO. 2 MAIN AND EXTENDED RANGE FUEL TANKS OF THE C-5 ARE APPROXIMATELY 55 INCHES DEEP. TANK ACCESS OPENINGS ARE LOCATED IN THE UPPER SURFACE OF THE WING. IN THE EVOLUTION OF THE WING DESIGN, IT WAS DISCOVERED THAT NO STRUCTURE WAS LOCATED NEAR ENOUGH TO THIS OPENING TO BE USED AS AN INTERMEDIATE STEP BETWEEN THE UPPER SURFACE AND THE FLOOR OF THE TANK. IT WAS

POINTED OUT BY HUMAN ENGINEERING PERSONNEL THAT THE SHOULDER HEIGHT OF A 5TH PERCENTILE AIR FORCE MALE IS ONLY 54 INCHES.

A MOCK-UP OF THE ACCESS OPENING WAS CONSTRUCTED AND PLACED AT THE APPROPRIATE HEIGHT ABOVE THE FLOOR SO AS TO ASSESS A MAN'S CAPABILITY OF EXTRICATING HIMSELF FROM THE TANK.

SLIDE 6 - <u>MOCK-UP OF WING ACCESS OPENING</u>

THE SUBJECT, A 65TH PERCENTILE MALE, ENCOUNTERED EXTREME DIFFICULTY IN GETTING UP THROUGH THE OPENING DUE TO HIS INABILITY TO GET HIS ARMS PLACED IN A POSITION ON THE UPPER SURFACE TO EFFICIENTLY LIFT HIS BODY WEIGHT.

STEPS WERE PLACED AT POINTS WHERE STRUCTURE WOULD ACCOMMODATE THE LOCATION OF A HORIZONTAL MEMBER. IT WAS FOUND THAT A STEP COULD BE LOCATED 40 INCHES BELOW THE OPENING AND THAT THIS STEP SIGNIFICANTLY IMPROVED ENTRANCE TO, AND EGRESS FROM, THE TANK.

SLIDE 7 - <u>WING ACCESS OPENING STEP</u>

THIS LOCATION WAS INCORPORATED IN THE WING DESIGN.

C-5A RUDDER HINGE AND ACTUATOR ACCESS

IN ORDER TO VERIFY ACCESSIBILITY OF THE RUDDER HINGES AND ACTUATORS, THE MAINTAINABILITY DEPARTMENT REQUESTED HUMAN ENGINEERING TO DEVELOP A FULL-SCALE MOCK-UP OF THE AREA IN QUESTION.

SLIDE 8 <u>RESTRAINING ACCESS AREA</u>

AS THE FIRST OF THESE PICTURES SHOWS, THE ACCESS AREA WAS FOUND TO BE RESTRAINING BUT ADEQUATE FOR PERSONNEL TO PERFORM THE REMOVAL, INSTALLATION

TASK. HOWEVER, THE MOCK-UP DID UNCOVER A SIGNIFICANT ERROR IN THE DESIGN OF THE RUDDER.

DURING REMOVAL OF THE RUDDER, BECAUSE OF THE MATING PROFILE OF THE RUDDER AND THE VERTICAL STABILIZER, THE RUDDER MUST BE PULLED STRAIGHT OUTBOARD IN ORDER TO CLEAR THE STABILIZER. EXAMINATION OF THE MOCK-UP DISCLOSED THE FACT THAT THE SKIN OF THE RUDDER COULD NOT PHYSICALLY CLEAR THE HINGE POINTS IN THE REMOVAL MANEUVER. COORDINATION OF THIS FINDING WITH THE DESIGN GROUPS RESULTED IN A PROVISION FOR REMOVABLE SKIN PANELS ADJACENT TO THE HINGE AND ACTUATOR CONNECTION POINTS.

SLIDE 9 - MODIFIED ACCESS OPENING

THIS MODIFICATION, SHOWN IN THE SECOND PICTURE, HAS THE ADDED ADVANTAGE OF INCREASING THE SIZE OF THE ACCESS OPENINGS, THUS IMPROVING MAINTAINABILITY.

MAIN LANDING GEAR BOGIE DESIGN

IN AN EFFORT TO OVERCOME PROBLEMS ASSOCIATED WITH HEAT TREATMENT OF THE C-5'S MAIN LANDING GEAR BOGIES, THE C-5 SPECIAL DESIGN PROJECTS TEAM DEVISED A NEW CONFIGURATION CALLING FOR A PRODUCTION BREAK AND MECHANICAL JOINT AT THE INTERSECTION OF THE BOGIE AND THE TRAILING AXLE. TO MEET STRENGTH REQUIREMENTS THIS JOINT INCORPORATED BOTH INTERNAL AND EXTERNAL FLANGES WITH BOLTS THROUGH EACH. IN ORDER TO DETERMINE MINIMUM ACCESS REQUIREMENTS FOR INSTALLATION/REMOVAL OF THE INTERNAL BOLTS, HUMAN ENGINEERING PERSONNEL CONSTRUCTED A MOCK-UP OF THE CRITICAL SECTION OF THE BOGIE.

SLIDE 10 - MLG BOGIE 3" ACCESS OPENING

THE THREE-INCH ACCESS OPENING IN THE REAR OF THE AXLE WAS FOUND TO BE ADEQUATE FROM A MANUFACTURING STANDPOINT BUT WOULD NOT MEET MILITARY STANDARDS FOR MAINTENANCE ACCESS.

SLIDE 11 - MLG BOGIE 6" AXLE ACCESS

SUBSEQUENTLY, IT WAS DISCOVERED THROUGH USE OF THE MOCK-UP THAT ACCESS TO THE INTERNAL BOLTS COULD BE ACHIEVED THROUGH THE SIX-INCH AXLE OPENING. THE BOLTING OPERATION CAN THUS BE PERFORMED BY TWO MEN WORKING IN COMBINATION AND UTILIZING OFFSET TOOLS. ACCEPTANCE OF THIS DESIGN BY THE AIR FORCE HAS RESULTED IN A SIGNIFICANT WEIGHT SAVING FOR THE AIRCRAFT.

C-5A NOSE RADOME ACCESS KIT

SIZE AND WEIGHT OF THE MULTI-MODE RADAR COMPONENTS LOCATED IN THE NOSE RADOME OF THE C-5A NECESSITATED DEVELOPMENT OF A KIT FOR ACCESS TO THESE COMPONENTS DURING INSPECTION AND MAINTENANCE. THE DEVELOPMENTAL STAGE OF THE MULTI-MODE SYSTEM PRECLUDED USE OF ACTUAL HARDWARE; THEREFORE, A FULL-SCALE SOFT MOCK-UP OF THE ANTENNA WAS CONSTRUCTED FOR USE BY THE AGE DESIGNERS. THIS MOCK-UP SERVED TO CLARIFY A NUMBER OF PROBLEMS INHERENT IN REACHING AND HANDLING THE VARIOUS COMPONENTS OF THE ANTENNA AND RESULTED IN THE AGE KIT DEPICTED IN THESE PICTURES.

SLIDE 12 - LIGHT WEIGHT LADDERS

THE KIT CONSISTS OF TWO LIGHT-WEIGHT LADDERS WHICH ATTACH TO THE AIRCRAFT STRUCTURE.

SLIDE 13 - WORK PLATFORM AND JIB CRANE

A WORK PLATFORM ATTACHED TO EACH LADDER AND A SMALL JIB CRANE FOR HOISTING COMPONENTS OF THE ANTENNA SYSTEM.

SIMULATED MAINTENANCE EXERCISES ON THE MOCK-UP DETERMINED THE PRECISE LOCATIONS AND SIZES FOR THE LADDERS, PLATFORMS AND CRANE. PROCEDURES WERE ESTABLISHED FOR REMOVAL OF THE VARIOUS SYSTEM COMPONENTS INCLUDING THE SEQUENCE OF ACTIONS REQUIRED TO PASS THE COMPONENTS THROUGH THE

ACCESS OPENING IN THE LOWER SURFACE OF THE RADOME. THIS WORK WAS A COOPERATIVE EFFORT INVOLVING HUMAN ENGINEERING, MAINTAINABILITY, AND AGE DESIGN.

STATION KEEPING EQUIPMENT (SKE) TEST SET

ONE IMPORTANT FACET OF HUMAN ENGINEERING'S CONTRIBUTION TO MAINTAINABILITY IS THE REVIEW OF, AND RECOMMENDATIONS FOR, DESIGN OF THE NUMEROUS PIECES OF TEST EQUIPMENT REQUIRED TO SUPPORT SUCH A SYSTEM AS THE C-5. AN EXAMPLE OF THIS ACTIVITY IS THE PANEL LAYOUTS FOR THE STATION KEEPING SYSTEM TEST SET.

SLIDE 14 - PANEL LAYOUT FOR SKE TEST SET

THIS PICTURE SHOWS A MOCK-UP OF A PORTION OF THIS TEST EQUIPMENT.

BRIEFLY, THE STATION KEEPING SYSTEM IS AN ELECTRONIC PILOTING AID WHICH AUTOMATICALLY MAINTAINS THE AIRCRAFT IN A DESIRED POSITION RELATIVE TO OTHER AIRCRAFT WHILE IN FORMATION FLIGHT. THE DESIRABILITY OF THOROUGH, PRECISE MAINTENANCE ON SUCH EQUIPMENT IS OBVIOUS WHEN ONE CONSIDERS THE SIZE AND SPEED OF THE C-5 COUPLED WITH THE REQUIREMENTS OF FORMATION FLYING.

NOT SO OBVIOUS IS THE ATTENTION TO DETAIL REQUIRED IN THE DESIGN OF EQUIPMENT FOR TESTING THE SYSTEM. THE IMPACT OF SUCH DETAILS AS STORAGE PROVISIONS FOR TEST AIDS AND MAINTENANCE MANUALS, PACKAGING, ACCESSIBILITY, LABELING, ADJUSTMENTS, TEST POINTS, FASTENERS, BUILT-IN SELF-TEST EQUIPMENT, FUNCTIONAL ARRANGEMENT AND GROUPING OF CONTROLS, READOUTS, ETC., CAN BEST BE UNDERSTOOD WHEN ONE CONSIDERS THE CAPABILITIES OF THE USER - - THE MAINTENANCE TECHNICIAN. AS POINTED OUT EARLIER, HE IS: "TYPICALLY A HIGH SCHOOL GRADUATE WITH FOUR YEARS OF MILITARY SERVICE, HAS COMPLETED ONE

BASIC TECHNICAL SCHOOL AND ONE ADVANCED TECHNICAL SCHOOL OF APPROXIMATELY THREE MONTHS DURATION". THE TEST EQUIPMENT SHOULD BE DESIGNED AS AN AID TO THIS MAN - - NOT AS A SECONDARY PUZZLE FOR HIM TO SOLVE BEFORE HE CAN ATTACK THE PRIMARY PROBLEM.

THE SOFT MOCK-UP SHOWN HERE WAS USED BY HUMAN ENGINEERING AS A DESIGN TOOL IN ANALYSES AND EVALUATIONS PREREQUISITE TO FINAL DESIGN. THIS APPROACH RESULTED IN THE INCORPORATION OF BETTER THAN TWENTY HUMAN ENGINEERING RECOMMENDATIONS WHICH NOT ONLY ENHANCED THE MAN-MACHINE INTERFACE BUT OBVIATED A GREAT DEAL OF DESIGN BACK-TRACKING IN DEVELOPMENT OF THE SKS TEST SYSTEM. THE MOCK-UP ALSO SERVED ADMIRABLY AS A VISUAL AID TO DISCUSSION WITH AIR FORCE REPRESENTATIVES DURING CRITICAL DESIGN REVIEW.

RUDDER SERVO CHEST PACK

A SERVICE LADDER, MOUNTED INSIDE THE VERTICAL STABILIZER, PROVIDES ACCESS TO THE RUDDER SERVO MANIFOLDS. TO REACH THE UPPER RUDDER MANIFOLD THE MAINTENANCE MAN MUST CLIMB APPROXIMATELY 27 FEET. IF REPLACEMENT OF THE 18-POUND MANIFOLD IS REQUIRED, THE MAINTENANCE MAN IS FACED WITH THE PROBLEM OF HOW TO HANDLE THE MANIFOLD AND HIS TOOLS WHILE ASCENDING OR DESCENDING THE LADDER.

A JOINT EFFORT BY HUMAN ENGINEERS AND MAINTAINABILITY ENGINEERS RESULTED IN THE PACK SHOWN HERE.

SLIDES 15 AND 16 - <u>RUDDER SERVO MANIFOLD CHEST PACK</u>

USING A PROPERLY WEIGHTED MOCK-UP OF THE SERVO MANIFOLD, IT WAS FOUND MORE DESIRABLE TO HAVE THE ITEM SLUNG IN FRONT OF THE MAN RATHER THAN ON HIS BACK SO THAT HE DOES NOT HAVE TO REMOVE THE PACK IN ORDER TO BRING THE MANIFOLD AROUND TO HIS WORKING POSITION. SINCE THE LADDER IS CANTED

AWAY FROM THE MAN AT AN ANGLE OF 32° FROM VERTICAL, AMPLE CLEARANCE IS PROVIDED BETWEEN THE CHEST PACK AND THE LADDER WHILE CLIMBING.

C-5A MAINTENANCE TRAINERS AND TECHNICAL PUBLICATIONS

MAINTENANCE TRAINERS

THE EXAMPLES GIVEN THUS FAR HAVE BEEN PREDOMINATELY IN THE DESIGN AREA. WE REALIZE THAT THE ABILITY OF THE MAINTENANCE MAN IS ALSO A FUNCTION OF THE SUPPORT CONSIDERATIONS THAT HELPS CONSTITUTE THE ENVIRONMENT IN WHICH HE MUST WORK.

PLACING EMPHASIS ON THE ABOVE PRINCIPLE, WE PLANNED EARLY IN THE C-5A DEVELOPMENT PROGRAM FOR RELIABLE SUPPORT EQUIPMENT AND JOB AIDS, INCLUDING MAINTENANCE TRAINERS AND TECHNICAL PUBLICATIONS. A REVIEW AND EVALUATION OF TWENTY-NINE (29) C-5A MAINTENANCE TRAINERS AND PANELS WERE CONDUCTED DURING JUNE-AUGUST, 1968.

BY ADMINISTERING A HUMAN ENGINEERING CHECKLIST; INTERVIEWING TRAINER TECHNICIANS, ENGINEERS, INSPECTORS, AND SUPERVISORS; AND BY OBSERVING MAINTAINABILITY DEMONSTRATIONS, THE ADEQUACY OF THE FOLLOWING TRAINER ELEMENTS WAS DETERMINED:

(1) VISUAL DISPLAYS

(2) CONTROLS

(3) LABELING

(4) WORKSPACE DESIGN

(5) MAINTAINABILITY

(6) HAZARDS AND SAFETY

OUT OF 420 COMMENTS AND RECOMMENDATIONS, 378 ITEMS (90%) WERE IMPLEMENTED. MAJOR CONTRIBUTIONS TO THE TEST PROGRAM WERE STANDARDIZATION OF TRAINER

NAME PLATES AND LABELS, IMPROVED QUALITY CONTROL, IDENTIFICATION OF THE NEED FOR MORE PRECISE DIRECTIVES TO SUBCONTRACTORS, AND IMPROVEMENTS IN CONTROL/DISPLAY, TRAINING EFFECTIVENESS, AND SAFETY.

TECHNICAL PUBLICATIONS

REVIEW AND EVALUATION OF TWENTY-THREE (23) C-5A PRELIMINARY MAINTENANCE TECHNICAL MANUALS (T.O.'S) WERE COMPLETED IN OCTOBER, 1968. THE FOLLOWING FACTORS WERE USED AS CRITERIA:

(1) ACCURACY

(2) COMPLETENESS

(3) READABILITY AND SIMPLICITY

(4) EASE OF USE (CROSS-REFERENCING AND INDEXING)

(5) FORMATTING

A TOTAL OF 509 COMMENTS AND RECOMMENDATIONS WERE MADE. ONE HUNDRED AND EIGHTY (180) OF THESE WERE RANDOMLY SELECTED FOR FOLLOW-UP ANALYSES AND, AT THE TIME OF THE ANALYSES, IT WAS FOUND THAT 60% HAD BEEN IMPLEMENTED.

SLIDE 17 - C-5A MAINTENANCE TRAINERS AND TECHNICAL PUBLICATIONS SUMMARY

THE MANUAL PRODUCTION PROCESS HAS A BUILT-IN TIME LAG WHICH SUGGESTS THAT THE CURRENT 60% VALUE SHOULD ULTIMATELY IMPROVE.

ARE THERE ANY QUESTIONS?

I WANT TO TAKE THIS OPPORTUNITY TO THANK YOU FOR YOUR ATTENTION. I'VE ENJOYED PRESENTING THIS PAPER TO YOU AND I HOPE YOU HAVE A BETTER INSIGHT INTO THE HUMAN ENGINEERING/MAINTAINABILITY INTERFACE ON THE C-5A. THANK YOU.

REFERENCE

MCABEE, W.H. "IS THERE A NEED FOR HUMAN ENGINEERING/MAINTAINABILITY INTERFACE?", LOCKHEED-GEORGIA COMPANY, MARIETTA, GEORGIA, NOVEMBER 1967.

THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM

Roll of Design Engineer
In Maintenance & Reliability

I. INTRODUCTION

A. Growth of Maintenance & Reliability as a Design Discipline --

The Aviation industry, as everyone knows, is slightly more than fifty years old, and until recently the mere fact that the aircraft flew on the day it was delivered was sufficient miracle it itself to justify the procurement. The earlier aircraft with simplified systems were not usually subject to service problems of a scope beyond the maintenance capability of the field mechanic or the pilot himself. Since the early 1940's however, the aircraft have become more and more sophisticated until it became evident that guidelines were required to establish maintainability requirements. These maintainability requirements, such as MIL-STD-470 dated 21 March 1966, are being applied as a integral part of the basic procurement contrac for new aircraft. In order to achieve the specified level of maintaintability in each new design, the designer must therefore apply the specified portions of these specifications in the initial design phase.

B. Estabilishment of Maintenance & Reliability Priority in Design --

1) Customer input through Marketing Department --

Assuming that a new aircraft design is the result of a customer request for contract, the customer must specify in the contract the degree of maintainability and reliability required. Seldom is a military standard such as MIL-STD-470 applied in its literal interpretation; therefore, interpretation must be made in the text of the procurement contract. As an example: a gear to drive a tachometer transmitter could be made of sufficient size to have infinite life with infinite reliability. This approach to reliability would obviously produce an aircraft so overweight that performance would be unacceptable. On the other extreme, weight could become such a factor in the design that each part would be so light that the life and reliability would be reduced to an unacceptable level. Compromises of this type must be made and it is the user's ultimate responsibility to define the mission requirement and adjust the other factors accordingly.

Presented at the FAA Maintenance Symposium THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM, at Oklahoma City, December 3-5, 1968, by H. S. Brindley, Project Engineer, Bell Helicopter Co.

2) Prior Experience in similar types --

In almost every new aircraft there are system elements which are carried over from prior aircraft. In many cases these components are the end result of years of development in similar applications with several aircraft models. Common sense and experience are irreplaceable virtues in a design engineer.

II. CONSIDERATIONS FOR MILITARY VS COMMERCIAL PRODUCT

A. Military Product --

1) The definition of Military Mission Environment --

When a contract is issued to procure a military aircraft, the mission of the aircraft is obviously the prime consideration of the new aircraft and usually the mission environment can be defined at the same time the mission is defined. In the case of Naval aircraft, it is obvious that salt air corrosion would be a prime consideration. In the case of an Army aircraft, more than likely dirt and conditions associated with army operations would govern. These factors all must be considered by the designer in the development of the new aircraft.

a) Military aircraft are usually mission oriented above all other considerations and in some cases as I am sure you are all aware, the aircraft can be considered expendable at the completion of a single operation,and in some cases can be considered expendable at the completion of a single mission. These missions are not judged on the basis of dollar profit, but as a degree of military gain. Consequently, endurance of components is not always a primary criterium in the development of military aircraft.

b) Pride of Ownership --

Most military aviators are active military aviators for a relatively short time. Even in the case of World War II,most of the pilots were discharged after no more than four years service. During their tenure of active duty, most pilots flew several types of aircraft, therefore, except in certain relatively short time overseas assignments the pilot never related toward his aircraft with a sense of ownership.

2) Definition of Military Maintenance Environment --

a) Known maintenance skill level --

Military aircraft are procured to fulfill the equipment requirements of a Table of Organization establishment. In this establishment, there are predetermined levels of maintenance skill defined by MOS qualifications.

b) Known maintenance facility level --

In conjunction with the known skill level defined above, the maintenance facility level also is established prior to design of the military aircraft.

c) Known maintenance logistics system

During the initail steps of design, provisioning conferences are conducted to define the logistics systems which will be used to support these aircraft.

d) Reacting time to Product Improvement Changes

After the aircraft are put in service and the design defects begin to become evident, maintainability is compromised by the time lag normally associated with ECP action for product improvements.

B. <u>Commercial Product</u>

1) <u>Definition of Commercial Mission Environment</u>

a) The commercial operation environment is infinitely varied when compared to military applications. In military usage comparatively large numbers of aircraft are usually operated from the same base, whereas commercial users frequently have one or two ship operations throughout the world.

In the commercial market, a market survey or similar system is used to determine the requirement for a particular aircraft. Almost all commercial aircraft are developed for speculative sales. Therefore, the development of commercial aircraft is usually based on assumed missions for unknown users.

b) Known operations for specific customers

It should be pointed out that the assumed operations listed above while comprising a majority of the market do not comprise the entire market. Obviously many commercial aircraft are developed for specific customers to fulfill stated missions. A case in point is many of the airline operations throughout the world.

2) Defination of Commercial Maintenance Environment --

a) Maintenance Skill Level

1) Assumed for Typical Customers

The maintenance skill level for commercial operators is regulated to the extent of A & P licensing. However, as everyone knows, there are mechanics and then there are "master mechanics". A twenty year old man with a new A & P license is not the equivalent of a mechanic with twenty-five years service on similar types of aircraft. On the other hand, the retirement age is such that a qualified OX-5 mechanic may be in the position of servicing turbine engines. Therefore, the designer must assume an average skill level for all maintenance personnel.

2) Known for Specific Customers

Seldom does a designer have the beforehand knowledge of the skill level of specific customers; however, the designer may assume that the maintenance people will be "standardized" by a decision to require special schooling at the manufacturer's facility. This can, therefore, be more or less partially successful in ensuring a specific skill level.

b) Maintenance Facility Level

1) Assumed for small operator

The designer must assume that a number of aircraft sold commercially will be operated by small customers. This type of operation is occasionally based at a facility comparable with the best in the world, but usually in the helicopter industry the small operators are operating from temporary facilities. Therefore, the designer must assume that a large part of the aircraft being manufactured will require maintenance without the benefit of suitable facilities.

2) Assumed for fleet operators

In the case of the large or fleet operators, a liaison can be established during the design phase which would enable the designer to have complete knowledge of the facility to be available for the aircraft.

c) Maintenance logistics systems --

1) Small operators using BHC Spares Department as depot

Most small operators rely on the manufacturer's Spares Department for an inventory of spare parts. The penalty that this type operator must pay is the time lost in procuring these parts from the factory.

2) Authorized service station for field depot --

Many manufacturers find it expedient to establish service stations or dealerships. In the case of these "field depots", the small operator can look to local sources for spares.

3) Fleet operators semi-self-contained --

In many cases, the fleet operator can establish a spares depot essentially equivalent to the manufacturer's spares department. Except for restocking these depots, these operators are virtually self-sufficient.

4) Foreign operations --

The foreign operator has in addition to the problems listed above, the problem of export and import of spare parts. In some so-called backward countries the local customs officials rely on "on the spot" quality for a source of income. Until the operator can establish political contacts, the delay of spare parts can virtually ground his operations. Most countries are honest in their customs sections, but still the delay can be a severe penalty on a commercial operation. The situations that can be encountered in foreign operations are so varied that each operation presents individual problems.

III. SPECIAL FEATURES TO IMPROVE MAINTENANCE AND RELIABILITY

A. Advantages of Diagnostic Systems --

In recent years, emphasis has been placed on diagnostic systems to improve maintainability by constantly monitoring the critical parts. The advantages of this system are obvious in most respects, however, a subtle advantage may be overlooked. Many components are overmaintained with the result that parts are actually damaged during the disassembly and reassembly operations. An effective diagnostic system would improve maintainability without compromising reliability in these cases.

B. Disadvantages of Diagnostic Systems --

The diagnostic systems have disadvantages in that frequently a failure of the diagnostic system will prompt an overhaul when the component in question was performing properly. The opposite situation can also be a disadvantage when the failure of the diagnostic system does not inform the pilot that an overhaul is required. Unfortunately, designers seldom apply the same reliability criteria to the diagnostic system as they do to the critical aircraft systems.

IV. SUMMARY AND CONCLUSION

A. The maintenance and reliability criteria has an ever increasing role in the basic design of new aircraft. The importance of this role is directly proportional to the degree of sophistication of the aircraft systems.

Aerospace technical progress is advancing at an exponential rate, therefore, maintainability and reliability must progress at the same rate in order to obtain aircraft availability or utilization factors comparable to pre World War II availability rates.

B. Role of Maintenance and Reliability in Reducing the Cost Per Cycle

Maintenance and reliability criteria can become an effective tool in reducing the cost per duty cycle of an aircraft. As an example, let us assume that a helicopter transmission requires a 600 overhaul. A detailed study of this transmission may reveal that two or three components could achieve an improved reliability if the heat treat were increased. Therefore, the reliability study may well increase the transmission overhaul interval to 1200 hours based on the improved reliability of the critical components. The obvious cost savings per duty cycle might well be the difference between profit and loss for a commercial operator or might well win the day for a battle field commander by increasing the aircraft availability rate.

C. Limitations to Designing for Better Maintenance and Reliability

The limitations to designing for improved maintenance and reliability are usually the users refusal to accept the cost, time, weight, or performance penalty in developing the best possible system components.

Beech Aircraft Corporation
Harry S. Gregory

The Men in the BEECHCRAFT Reliability Program

There are 21 different third level airlines in the United States using the 99 Airliner. Most are located on the East Coast. The number, however, is increasing daily and use is spreading to the South and West.

As of November 15, 1968 there were 43 BEECHCRAFT 99 Airliners delivered and in use in the United States and throughout the Free World. We have two BEECHCRAFT 99 Airliners in use in other countries. The aircraft we have in service have flown a total of 20,000 hours or 5 million miles.

The first 99 Airliner to reach 1,000 hours flying time was Serial U-8 belonging to Air Wisconsin. Last month, Mr. Frank Hedrick, President of Beech Aircraft Corporation, presented Mr. Ed Godec, Operations Manager of Air Wisconsin, with a plaque which read:

> "In recognition of the first 1,000 flight hours accomplished by a BEECHCRAFT 99 Airliner. This was accomplished by Serial U-8 in 4½ months of Commuter Airline Service to communities in Wisconsin, Illinois, and Minnesota. 1,000 flight hours represent approximately 250 thousand miles of flight -- equivalent to a trip to the moon. It also represents a significant milestone in maintaining a vital link in modern transportation."

The schedules of these third level airlines are quite different from those of the major airlines, who have lengthy routes with usually an hour or more between stops The majority of 99 Airliners have 20 to 45 minute block-time schedules, with the average being about 30 minutes.

There are also various types of operations. From the 1 and 2 airplane operator to the fleet owner of 25 or more airplanes. Commuter Airlines, out of Chicago, has 8 99's in service and more on order. In addition to the use of the BEECHCRAFT 99 Airliner, these operators are using the other heavy twins like BEECHCRAFT Queen Air and many are using the BEECHCRAFT Baron and other smaller aircraft.

One of the programs we pointed out last year was our Maintenance Reliability Program and how we anticipated fast action on problems. We have had three major opportunities for improvement on the 99 Airliner.

The first of these involved the landing gear actuator. The problem stemmed from the fact that a newly designed actuator used on the BEECHCRAFT 99 Airliners was such that if the landing gear was not rigged exactly right, it was possible for the actuator screw to reverse itself and cause the gear to retract. The new actuator was very similar to the one used on the King Air and Queen Air Models which had thousands and thousands of hours of service. However, as sometimes happens when you have a brand new program and try to increase efficiency, you make things too good. This is what happened with the jack screw. We increased the gear speed, but with the change there simply was not sufficient drag on the internal mechanism to make it totally irreversible.

As an interim fix we actually put a mechanical drag brake on the actuator. This prevented free movement of the actuator so that it could not reverse itself, but was not enough drag to put an overload on the motor. I think it's interesting to note the amount of time it took from investigation of the problem until the fix was in the field.

A meeting of all concerned was held on Tuesday. It was determined that a permanent type fix would be a long, drawn out affair requiring a new type actuator and parts that could not be supplied immediately; and, therefore, it was necessary to have an interim fix. The job was given to the Design Group to develop the interim fix on the same day.

By Friday night the Design Engineers had developed a pony brake, and orders were delivered to our Manufacturing Department. Four units were manufactured over night.

On Saturday morning the system was installed by the Flight Department in an airplane on which trouble had previously been experienced. Tests were run and the pony brake proved satisfactory. F.A.A. personnel were on hand during the tests and they approved the fix. Production continued on additional parts.

On Sunday morning Service Personnel were on airplanes with parts enroute to various users. The remaining parts were shipped Sunday evening.

By Monday evening parts were in the hands of all users. In less than a total span of 7 days, we came from the problem to the solution, to field retrofit. This cannot always happen, but it can happen easier when the program is set up to handle this type of quick interim fix.

A similar instance happened on the stabilizers and elevators of the 99 Airliner. We found, after 400 to 500 hours of operation, small cracks developed around certain flush rivets in both stabilizers and elevators. It was determined that cracks developed because, in some cases, the rivet heads did not get full engagement with the skin. In other words, the countersunk portion of the hole went clear through the skin and into the structure, so the head had insufficient bearing surface with the skin.

For field fix it became necessary in some instances to drill out the countersunk rivets and replace them with Brazier head rivets of a larger size. On some in-service units it was necessary to repair cracked stabilizer and elevators. On Serials U-58 and after changes were made which eliminated the problem altogether.

The third major challenge area that has developed is in Avionic equipment, and, I feel that this is a problem in many airplanes. However, the Avionics equipment used in the 99 Airliner is not the exotic type equipment used in the larger airliners. Nevertheless, a few bugs were expected and they did arise. Primarily, the problems were caused by certain connections being loose and by antenna locations. A team of two Avionics Personnel was dispatched to each Airline having difficulty and the problems were solved on the spot.

With the major items behind us we look for ways to improve reliability and maintenance overhaul periods. One of the items we are continually trying to increase is the PT6 engine overhaul period.

The P & W PT6A-20 engine used in the 99 Airliner has proven to be as reliable in this application as it is in the King Air Program. While the engine TBO is set at 1,900 hours for initial users, plans have already been developed to up time to 2,300 hours, with future plans for progressive engine maintenance.

The progressive plan calls for hot section inspection and minor component replacement at 1,000 hours and 2,000 hours respectively with major component replacement at 3,000 hours.

Gentlemen, "The reliability of any reliability program depends on man."

We feel that at least part of our success started with our instructors both in Maintenance Training and in Operational Training. We feel that training is the key to our Reliability and Maintainability Program, and we have our Instructor as a key man in getting this program started.

It is up to the instructor to make sure personnel know how to operate and maintain the airplane properly. Many of the maintenance personnel have worked on less complicated aircraft and it is quite an indoctrination to move them up to maintaining the BEECHCRAFT 99 Airliner with its more sophisticated electronics, different type retractable gear mechanism, movable stabilizer trim, and other innovations new to the small airplane maintenance man.

We have found it most imperative that you get a good start with a good training program. That is why we say a key man in our Reliability Program is the instructor.

Where do you get an instructor for mechanics who are going to be working on airline airplanes? It isn't easy to find one man with all the qualifications, so we have three. All are excellent maintenance instructors but each has something additional. Scott Hutchinson has an impressive background including working for the F.A.A. He can point out the need for, and ways to comply with, regulations. Bill Faltoner is a retired military maintenance officer who can help provide the know-how for organization which is so badly needed in all shops today. And Bruce Addington, who has previous airline shop and fixed base operation management experience.

The Training Program, as we now have it, consists of 2 weeks schooling for the mechanic. This covers troubleshooting and operation of all systems, the power plant and electronics. It does not include avionics.

Also in order to have good maintenance reliability, it is necessary for the A & P mechanic to become skilled in his job. Our Service Engineers work with the A & P mechanic at his home base to make the A & P mechanic a key man in his organization.

I'd like to read a paragraph from Air Wisconsin's House Organ. Quote: The unsung heroes of Air Wisconsin seldom receive credit for our "on time" record performance. Obviously we are talking about our mechanics -- but not often enough. Unquote. Thus the A & P mechanic becomes another key man in our Reliability Program. How do we help this A & P who is such a strong link in our reliability chain?

In addition to our own training on the airplane, we have set up an Apprenticeship Program, sanctioned by the U.S. Department of Labor, Bureau of Apprenticeship and Training. Through this program we will help develop future craftsmen for our industry. We have worked with one school and will work with others to set up special programs geared to General Aviation and the 99 Airliner Program.

Our Apprenticeship Program is based on initial training in good approved schools followed by on the job training. This type of program is necessary, for many in third level airline business are located in smaller communities than the major airlines. We need to train home town boys who want to stay in the community, so they become skilled aircraft mechanics.

We have outlined a program of instruction that can be used by an airline operator to start a man on such an Apprentice Program. He is paid while working -- but not while going to school. The program is approved so that if he is a G.I. he can get government benefits. After completing the program, he becomes a qualified A & P Aero-mechanic.

Some of the airlines were formerly smaller operators and had only one or two mechanics, shop management was not a problem; however, now that they have schedules and more airplanes, shop management becomes extremely important. Because of this we are outlining a proposed course for service management.

We will have management council meetings where various aspects of usage of time, management skills and cost accounting will be discussed. The airline maintenance man is certainly a key man in reliability.

In the middle, trying to help both the instructor in getting the correct information, and then into the field to make sure the maintenance man is using the information correctly is the Service Engineer. He is a combination salesman, father confessor, mechanic, pilot and an all-around troubleshooter.

At BEECHCRAFT we have the General Service Engineer and then we have the Specialist on engines and on avionics. Their average experience in the aircraft business is 17 years.

They are all holders of A & P Mechanics Licenses and most of them have some airline maintenance experience. They all hold at least a private pilot's license. All have college degrees or trade school backgrounds. Men like John Lawler from Northrup Institute; Larry Hamlet formerly with American Airlines and others with similar experience.

These men make regular scheduled visits to airline operators, plus extended visits on call. Because of the fact we have our own transportation fleet of airplanes available, and our location puts us but a few hours from any place in the United States, we have not assigned a Service Representative at each airline operation. We are as close as the operator's telephone -- and, believe me, they use it 24 hours a day.

We are, at the present time, considering the possibility of assigning representatives to certain areas to provide service to a particular group of airline operators, and making periodic visits to only his own area.

This Service Engineer is the key link between the Factory and the user in our Reliability Program.

At home the Service Engineers' duties include the writing of discrepancy notices so that information may be passed on to the Engineer and to the Workman in the Factory to help correct any deficiency that might be found, be it design or workmanship.

I mentioned to you previously that we had three major challenge areas. These are not all the challenges we've had. During the first six months period the 99 Airliner was in service, our Service Engineers have written 73 discrepancy notices on which Corrective Action was requested.

When a discrepancy notice is marked for action, it goes immediately to the Corrective Action Committee. The Committee and its function was described in detail during last year's meeting, but I will review it briefly here. The Committee is composed of representatives from Engineering, Manufacturing, Inspection, Service, Tooling, Procurement, and Planning. The problem on which action is requested is assigned to the person whose department is responsible.

It then becomes his responsibility to see that an answer is returned to the Committee as soon as possible. By an answer we mean a complete answer. If a change is in order, it includes the design change, schedule of incorporation of the change in the airplane and the field service retrofit requirements. It is the responsibility of the Service Engineer to follow through on action he has requested to see that action is taken.

And now we come to the last, but far from the least, link in our Reliability Program - the Design Engineer. It is the Design Engineer's job to look at his design and see how he can better it. He is always concerned that the way the aircraft is being used and the design is compatible. Needless to say, we are learning each and every day. In fact, it is like no program any aircraft manufacturer of this size airplane has ever encountered. The information we are now receiving through our field service organization and directed through our data feedback system to our Engineers is being used in design of present and future aircraft. This then, makes the Engineer the key man at the Factory.

What kind of motivation do we provide the Engineer to design the reliability we need into the airplane. The easiest motivating power we have found is to put the Engineer on the firing line. We have taken our Engineers to the Airline to witness inspections and to discuss problem areas. This way they hear first hand what the problems are and actually see how they relate to the operation. They return home with sore posteriors and renewed vigor.

We have also had Engineering set in on our Maintenance Review Board sessions with the Federal Aviation Administration and the Operators. As you know, we are not actually operating under FAR 121 which requires Maintenance Review Board action. However, Beech took the lead and developed an inspection guide with the help of the F.A.A. and then had a Maintenance Review Board Seminar with Operators and F.A.A. in attendance.

We have received fine cooperation from all concerned and the F.A.A. has now published a preliminary copy of their maintenance inspection recommendations for the BEECHCRAFT 99 Airliner. The inspection guide will be used as a basis for all new operators maintenance. When they can show cause, these requirements can be changed to fit their particular shop. This guide is also a help to those already in operation to act as a check on their maintenance procedures.

I would like to take this opportunity to officially thank the Federal Aviation Administration for the cooperation.

So the Engineer now completes the cycle in this Reliability Program. When I talked to you a year ago, the Engineer was the first man in our program, and the ultimate user, the last. Now, with the airplane in service, the situation reverses and the user becomes the first man in the program and the Engineer the last.

We say again the reliability of any reliability program depends on man.

The key is to keep him motivated. This cannot be done by salary alone. It must be done through sincere praise and recognition for the job that is being done. Whether this be an instructor, the A & P mechanic, the Service Representative or the Engineer -- he must be treated with respect and his importance recognized. Each of these people must know their role in the big picture to work efficiently with each other and with their fellow employees.

They must be able to communicate! This skill in communication cannot be over emphasized. We are stressing in our programs to make your point by being not only good at your job but by being able to transmit the information concisely, simply and correctly. The machine is impersonal; we can feed it material without thoughts as to whether or not it likes it. The man, however, has feelings and if he is going to be a reliable key in our Reliability Program, he must be given the proper attention.

In our program we use modern statistical management guidance systems for planning, development, training, follow-up, feed back and service correction.

We have a computerized reporting system and fast action follow-up.

We also have a sincere desire to give good, honest, fast service to the customer.

We have a program to recognize the men and the job they are doing.

These, along with a lot of good, old fashioned, hard work, are getting the job done.

We will soon be coming into the phase in which the number of aircraft we have in service will exceed the number our Service Personnel will be able to handle under the present system.

So we cannot sit still resting on our laurels. Changes are required, and we are willing to change.

We are looking at new programs, and are here today in hopes of getting information from the reliability men in the airline business. Perhaps we can pattern some of our maintenance programs after theirs.

But rest assured, we will find the answers and, through maintenance men, provide continuing service to our customers.

Thank you.

GE ADVANCED CONCEPTS FOR POWER PLANT MAINTENANCE

INTRODUCTION:

General Electric welcomes this opportunity to discuss some of the things we have been working on in the way of advanced maintenance concepts to go along with our advanced technology engines. For the purpose of this discussion, we will concentrate on maintenance mostly as it applies to the CF6 power plant for the DC-10 rather than the GE4 supersonic transport engine for the Boeing 2707 since the CF6 is closer to operational status. Also the talk will try to concentrate on the efforts being placed on "human engineering" -- the man in the maintenance reliability system. To intermix a little philosophy into our thoughts -- the discussion has been broken into several concept sections -- each introduced by a little maxim.

FIGURE I, MAXIM NO. I

"Mini-Maintenance takes Maxi-Planning"

Too often maintainability has been an after-thought. Weight performance, integrity, and cost have received most of the emphasis. Good design standards and personal understanding of airline maintenance requirements have resulted in engines that have been reliable and fairly maintainable.

But surely a more disciplined look at maintenance requirements during the early design phase could have made the airline maintenance man's job a bit easier. This is especially true of the powerplant installation. Here designers in the past have been so concerned with weight and nacelle drag that maintainability has likely been of secondary consideration.

FIGURE II - DC-10 NACELLE

On the CF6 engine installation of the DC-10, GE installation engineers worked directly in the aircraft manufacturer's plant for many months to optimize maintainability. We believe the results show the worth of this combined effort. First, after many discussions with potential airline users, it was decided to place the accessories on the fan casing; extra weight -- but far more maintainable. To take advantage of this location, nacelle designers devised quickly opened fan cowl doors.

Presented at the FAA Maintenance Symposium, THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM, at Oklahoma City, December 3-5, by David R. Moss, Manager, CF6 Support & Field Engrg., General Electric, Cincinnati, Ohio

FIGURE III - QUICK ACCESS

72% of the CF6's line replaceable accessories are exposed by simply raising these doors. The doors weigh 100 lbs. each, but because of the top hinge, one man can easily swing them open. Much care has been given to the arrangement of the control of accessories to assure simple installation and removal. The fan reverser assembly splits to quickly expose the remaining accessories and the core engine.

FIGURE IV - ACCESSORY GEARBOX

Mock-up studies made with airframe manufacturer and airlines have been directed at arriving at an accessory gearbox configuration which will provide accessibility and fewer nicked knuckles. With large fan casing to spread the accessories over, the accessory spacing has been made quite wide with this consideration in mind. Accessories are also positioned to optimize piping lengths and routing. Result: less chance to mangle the piping.

FIGURE V QAD MOUNTING

An example of how manufacturers now put stiff maintenance requirements on designers -- most CF6 accessories are required to take less than 30 minutes to change. One good means to better this goal is to use quick attach-detach mounts on accessories. This QAD mount is used on GE4 accessories -- but is typical of one type used on the CF6. It is perhaps appropriate to note here that the GE4 designers are, of course, every bit as concerned with maintainability as the CF6 designers. However, there is still quite a bit of the GE4 installation design which is flexible.

FIGURE VI DESIGN FOR MINIMUM MAINTENANCE ERROR

There are just a few examples of planning ahead for maintenance. Other ways in which the maintenance man has been considered in the detailed design of the CF6 are shown in this example (Figure VI). The design requirements of all General Electric engines under development now contain such maintainability rules.

Large engines, in addition to detail maintainability features must consider the problems of sheer size. Which leads to the next maxim.

FIGURE VII MAXIM II

"40,000 + lbs. thrust engines are big unless divided into smaller pieces".

FIGURE VIII - CF6 ENGINE IN TEST CELL

The CF6 size is typical of the advanced transport engines offered in the 1970's. Almost 8 foot in diameter at the fan end -- and weighing about 3 3/4 tons without QEC, and over 5 tons when equipped with complete QEC. All such engines seem to exceed the current 96" highway transport limit for shipping when cowled.

FIGURE IX GE4 ENGINE

The GE4 is not as large in diameter, being a turbo-jet instead of a high by-pass fan. However, being a 67,000 lb. thrust engine equipped with an augmentor and subsequently two nozzles, it is over 25 ft. in length. The weight without the inlet or cowling forward of the augmentor is about 6 tons. Handling of such large engines can certainly be a problem. One way to minimize this problem is to modularize. Both CF6 and GE4 are therefore designed with modular maintenance and shipment in mind.

FIGURE X CF6 ENGINE MODULES

The CF6 separates into several major components, as will the GE4. The CF6 is shown here in exploded view. Let's look at the modules separately.

FIGURE XI THE FAN FRAME

The fan unbolts from its drive shaft at the front and -- permitting handling the fan separately, or the fan, its casing and bearings as a complete module. For maintenance, fan blades, fan and blade assembly, or complete fan package are removable with engine installed on either wing location. The gearbox is a separate module, readily detachable from the fan casing.

FIGURE XII - COMPRESSOR + HP TURBINE (CORE ENGINE)

The CF6 and TF39 C5A engine are unique among transport engines being built around a core engine, which can be run and tested separately. More of this later -- but this core engine consists of two separate modules -- the compressor and the high pressure turbine.

FIGURE XIII THE LP TURBINE

The low pressure turbine module consists of a 5 stage turbine rotor with a mid frame, rear frame, casing and its own bearings.

The modular breakdown provides a number of interesting and important changes to the concept of engine maintenance. First, as one airline has pointed out to us, neither the CF6, or any of its rivals will fit in any current commercial transport except the Lockheed Hercules. They won't fit in cargo versions of 707 or DC-8; not as a whole engine -- but break the CF6 into modules and

and all pieces except the fan frame will fit in the belly hold of a 727! Even the fan rotor itself is readily de-bladed and the hub, properly protected, would fit into a belly hold.

FIGURE XIV ON-WING MAINTENANCE

Modular design readily makes this type engine more adaptable to on-wing maintenance. Here we have pictured a concept being worked-on to permit removal of engine components down to combustor. Maintainability studies indicate it may be possible to make such an on-wing combustor change easily during an over-night maintenance check. Why not?

FIGURE XV CJ805

This is a photograph of the change of a CJ805 turbine by TWA at their LAX maintenance base during an "over-night" check. The elapsed time to drop the engine to the floor, perform the turbine package change, re-assemble and re-install the engine, including run-up was less than 8 hours. This was accomplished on an engine designed before there was a need for field disassembly. And this was the first time attempted. All of which indicates that new maintenance concepts are feasible if understood and planned for.

FIGURE XVI MAXIM III

"If modules are changed on the wing - interchangeability is king"

FIGURE XVII CROSS SECTION OF CF6

Advanced technology engines are very high compression -- and their performance depends upon close clearance control. Furthermore, they have large mass fans and rotating systems -- so balance can be critical. The CF6 had to consider this carefully in its basic design. It's length, for instance, is necessary to permit its "different" character. It is basically a simple separate core engine -- a three bearing turbojet gas generator much like its J79 predecessor -- aerodynamically separable from both the fan and the fan turbine. Interestingly enough, the demonstrator for the TF39 and CF6 was a GE1 65 lb./sec. turbojet with its center bored out to accommodate the fan shaft.

It ran first as a turbojet, then the rest of the engine was built up around it -- right in the test cell. We didn't even have to change the fuel control. The fan merely supercharged the core -- the control sensed the change in P_2 and T_2 and compensated.

FIGURE XVIII CECT ENGINE IN TEST CELL

The first experimental TF39 was built in the test cell the same way. More than interesting, this has permitted GE to gain much valuable life experience by running core engine cyclic endurance tests.

We believe this may make it possible to develop maintenance concepts based on not testing complete engines. Presently, newly overhauled engines are always tested -- partly to assure it was put together properly, and partially to trim the engine. Repaired engines may or may not be tested. Many airlines make it a practice to test every repair job because there have been many test cell rejects -- too often just for balance or leakage.

Can test cell running be minimized or eliminated? We believe it must be the objective of a successful modular maintenance plan to permit change-outs of modules at other than main bases where test cells exist. And, in fact, hot sections or change-out of turbine packages in the field today require only on-the-wing run-ups to prove balance has not been distrubed, and to check out system integrity. However, it has taken a lot of work before airlines convinced themselves they could interchange turbines, or even remove and replace the same turbine during an overnight check without a good change of missing a morning schedule. It is our aim to permit interchange of CF6 modules in a few hours without concern for run up rejection.

The core engine concept helps considerably in this objective. Since the core is not matched aerodynamically to the fan or low pressure turbine, a change of LP turbine or fan module has little effect on performance. For the CF6, it is planned to utilize fan RPM as the thrust setting parameter, and fan or low pressure turbine efficiencies have little effect on net thrust. It would take a 5% change in low pressure turbine efficiency or a 10% change in fan efficiency to change the thrust/fan RPM relationship by one percent.

Since such efficiency differences are almost inconceivable between serviceable modules, low pressure system modules can be interchanged without concern for performance or aerodynamic mismatch. In fact, there is no aerodynamic trimming of the CF6 engine contemplated -- even for engines which have been completely rebuilt.

Balance of the LP system is also simpler with the CF6 design, because both the fan module and LP turbine module run on their own separately supported bearings. This system does an excellent job of isolating vibration and reducing chance of a resulting "shaker" when replacing one low pressure module with another that meets balance limits. The possibility of unanticipated vibration interaction has been a deterant to changing turbines without concern on our current engines.

Incidentally, since tight vibration limits are so important to assure trouble-free engine operation, both the fan rotor system and low pressure turbine are separately trim balanced on the CF6.

The ability to interchange low pressure modules without concern for performance or balance, combined with the care being taken to simplify interchange, can mean whole new concepts of engine maintenance procedures

may be developed -- many of these due to work between GE and airline customers accomplished before the CF6 enters service. And so we come to another maxim:

FIGURE XIX MAXIM IV

"Even astronauts don't work in a vacuum."

FIGURE XX PICTURE OF TEAM UNDER CF6

During the early design days of the SST competition, the evaluating airlines under the able direction of Bill Ment... of United formed airline teams which guided both airframe and engine manufacturers toward improving their design to achieve truly airline oriented equipment. The real experts in the airline business are the people who are under constant pressure to keep the mechanical delay rate under something like one percent. Delay rates haven't had any significance at all to most designers. They also have often thought of "life" more as ultimate achievable life; not primarily as time between repairs. But not any more! The SST propulsion team carefully critiqued designs for maintainability, durability and reliability, and as the designs are tested and modified, they are continuing to look over the designer's shoulders.

This successful means of cooperating to achieve optimum design from the airline viewpoint has been carried a step further with the CF6 Coordination Team. This is a combined engine manufacturer, airframe manufacturer and airline operator committee which has met continually to critique not only the engine design, but also the installation design, and the support plans of the manufacturers. The results of airline/manufacturer coordination are coming to fruition, as team efforts to optimize the engine for maintenance, and the maintenance development plans to fit the envelope of the engine and installation limitations. The results will further be combined both in the maintenance instructions that become the approved light and heavy maintenance manuals -- and something new, the trouble-shooting manual. A true systems approach to maintenance.

Simple? Of course, but until the SST competition, it was unheard of. And, we believe it is carried to the proper "pressurized" environment with the CF6 installation.

Only a couple more maxims and we will have completed our viewpoint in helping the man in the maintenance picture.

FIGURE XXI MAXIM V

"Diagnostic equipment doesn't prevent - it anticipates." This may be a little oversimplified - but the theme is important.

Reliability comes from proper design, adequate development testing, and understanding of the basic cause of failures when corrective action programs are instituted. Condition monitoring or diagnostic equipment and techniques may assist in determination of serviceability but can't in itself improve reliability. The General Electric approach therefore is to develop diagnostic techniques and to test promising equipment during the development program, and combine this with a reliability program that is aimed at making the engine ready for condition monitored maintenance when it enters service.

Many promising types of equipment are under development both for fault recognition and fault isolation. A good example of the former is the presently used accelerometers -- or the more complex vibration analyzers. We have been doing much work with many types of vibration devices and anticipate improvement in the state of the art -- proven during development and in flight evaluation by the time the CF6 enters service. A second piece of equipment which offers great possibilities in fault recognition is the oil analyzer currently under development at GE.

FIGURE XXII OIL ANALYZER

This newest version of the analyzer uses an optical method of determining oil quality and type contamination if metal particles are present. It could be airborne or plugged in for ground inspection. The basic design will be further defined and tested during the CF6 development program.

Once vibration indication, performance deterioration or oil contamination indicate engine difficulty exists, the problem must be isolated and evaluated. And so we come to the first maxim.

FIGURE XXIII MAXIM VI

"Looking from the outside beats the Dickens out of teardown."

This one is obvious. However, it points out one of the fastest growing arts in the aircraft industry -- the development of the fault-isolation equipment.

FIGURE XXIV BORESCOPE

All three engine manufacturers have been cooperating with the optical hardware people to design borescopes which can twist and plunge and zoom and focus sharply. The new designs are a far cry from the old proctoscope which we once used to see if a valve was burned or a piston top-land was missing. The borescope does, however, have limitations. There are 29 casing locations where a borescope can be inserted in a CF6. But it can't see around all the corners. Furthermore, it is really a time consuming job to borescope an entire engine. For this reason, it hasn't looked feasible to routinely inspect for general engine condition during

periodic inspections. However, when a known problem exists, the borescope can normally detect the problem without teardown requirement. Furthermore, the picture resolution -- even when photographed on 35mm film -- is truly excellent.

Should a decision be made that borescopes should be used for routine inspections, there is a need for automated and photographic means for recording the condition.

FIGURE XXV BORESCOPE TIME

General Electric has tried several methods of recording borescope views on both photographic and TV tape recording methods. This view shows that auto-scan offers considerable time advantage over conventional means of borescoping. When recorded on photo-film, the system also offers the advantage of trend analysis through visual deterioration time progression records. Combustor cracks, for instance, are not alarming. It's the rate of crack progression which determines when corrective action is required.

FIGURE XXVI

Another promising means of external inspection and fault isolation is the well known radiographic method. Radiographic inspection technique development is the key to effectiveness. Both CF6 and GE4 are "wide open" in radiographic terms, the GE4 engine because of its size -- and the CF6 because of its length. This helps permit the development of taking clear shots of possible critical areas that the borescope might miss. Here we see the turbine area of a GE4 -- a shot taken radially. We have been experimenting with radiographs taken at oblique angles and they have shown excellent details of cool hole features not visible in the radial shot. Thus radiographic inspection supplements the borescope in fault isolation -- and may in some areas make the use of borescope of secondary need -- or only used to further verify radiographic indications.

Another new and very promising external inspection device is the radiometer. We are actively pursuing this as a means of assuring turbine blade integrity is not deteriorating. This device works by photo-electric crystal measurement of infra-red emission directly from turbine blades. This model is liquid cooled and weighs a couple pounds. Lighter-weight models are possible for airborne blade temperature inspection, and are currently under development.

FIGURE XXVII RADIOMETER ANALYZER

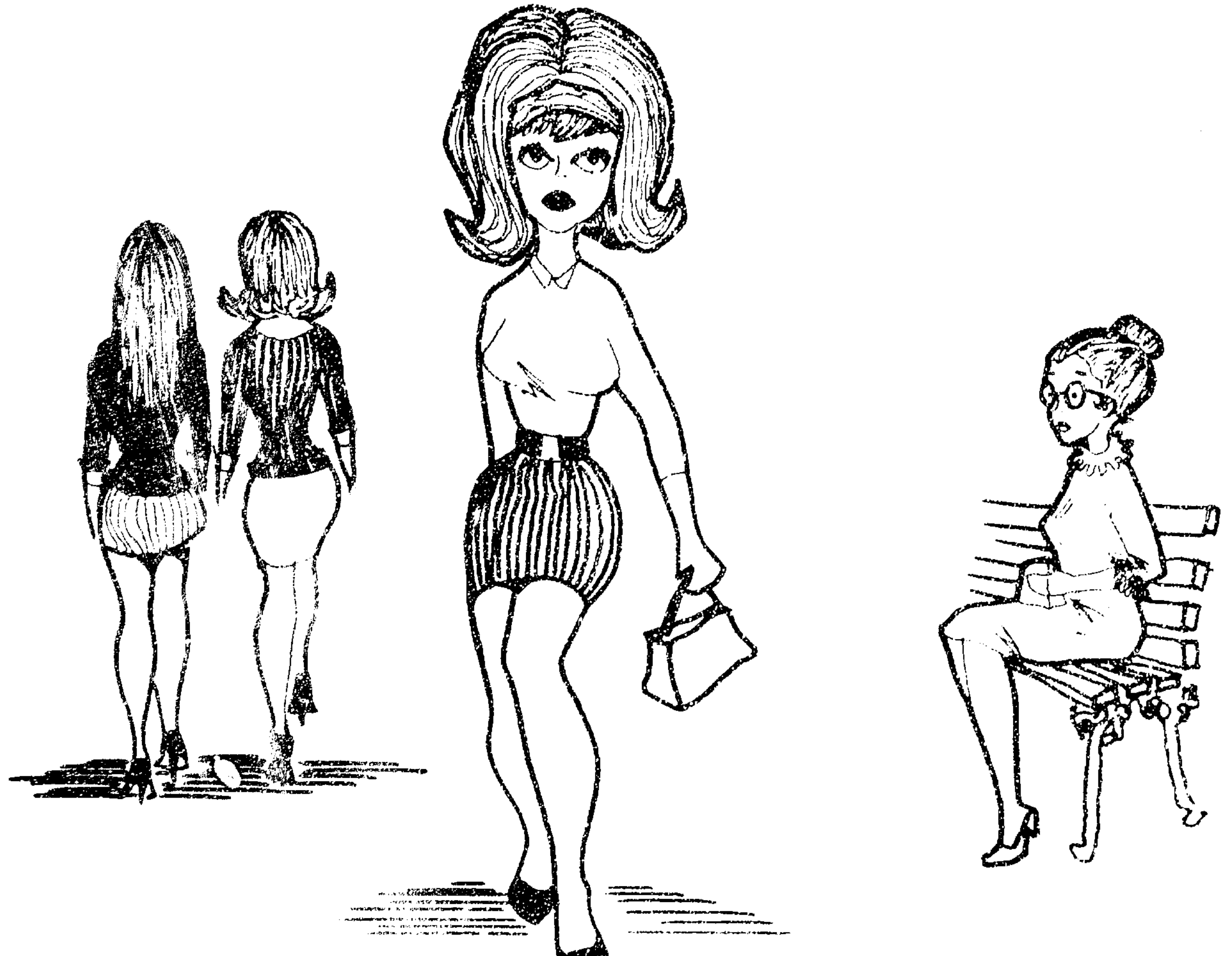
The real trick to effectiveness of radiometer devices is to have the capability of interpreting what the photo-electric crystal sees. It presently takes a pretty sophisticated piece

of electronic gear like this to measure each blade separately, or to average the complete spectrum of infra-emission from all the blades. The present thought to use trend information to detect variation in anticipated infra-red emission -- and isolate the blade or blades causing the change in emission by an electronic switching technique.

THIS BRINGS US TO THE CONCLUSION

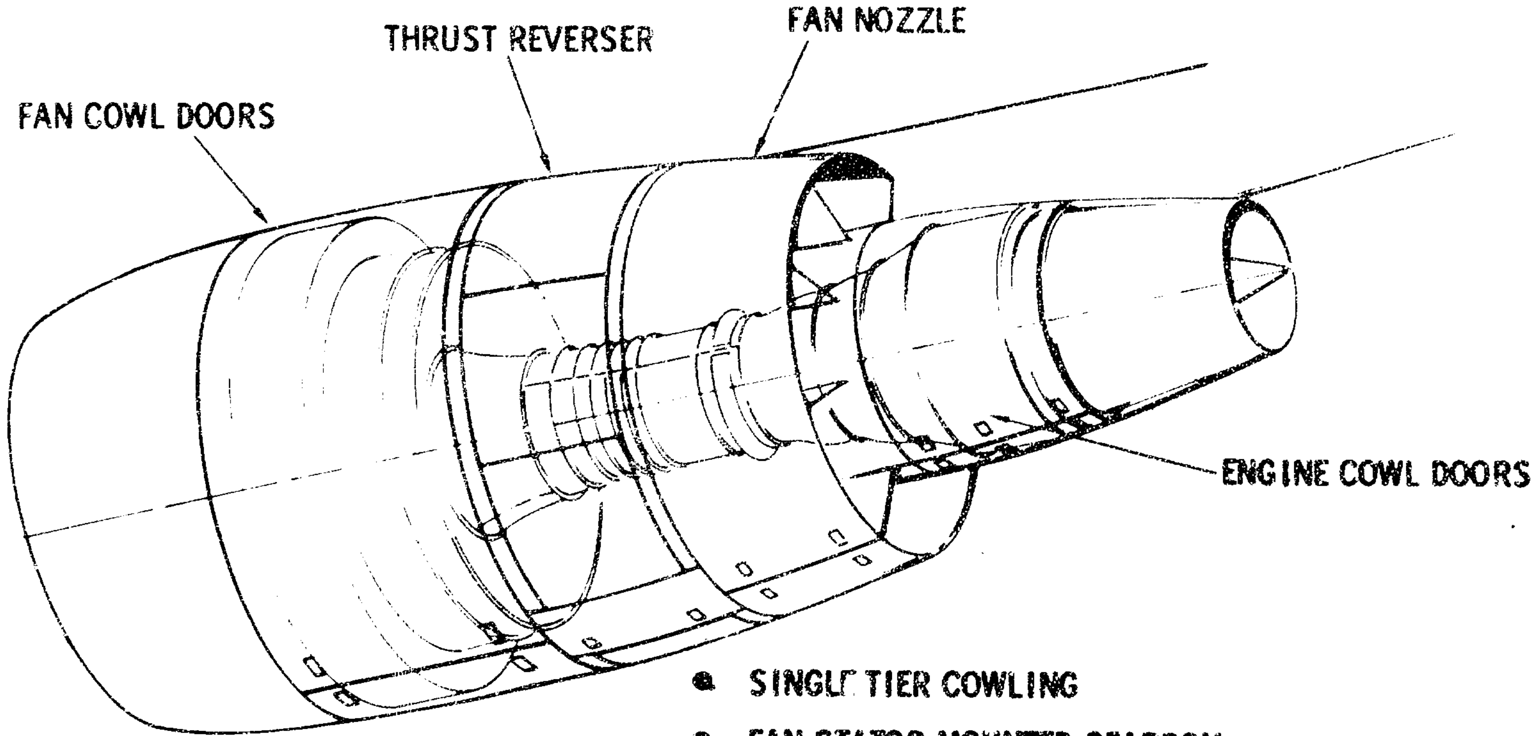
We at General Electric believe in the condition-monitored approach to maintenance. But it takes more than words and hope to "get there from here." It takes much planning as maxim #1 points out. But it also requires much cooperative effort between manufacturers and airline customers during the development phase of new equipment. And it takes tangible evidence through testing and try-out of the special equipment and techniques. Probably most of all it takes understanding of the limitations of both man and machine.

MAXIM NO I



Mini-maintenance takes Maxi-planning

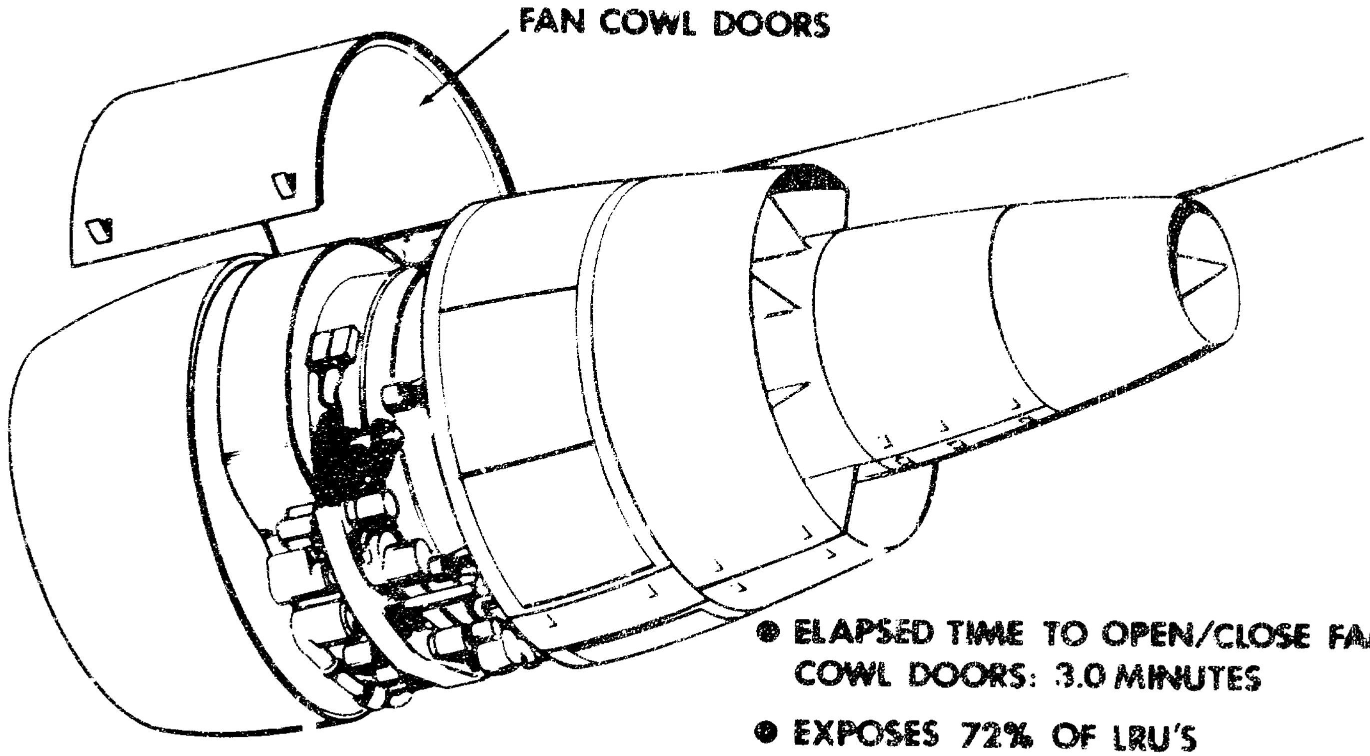
CF6/DC-10 PROPULSION SYSTEM



- SINGLE TIER COWLING
- FAN STATOR MOUNTED GEARBOX
- MOST LRU's LOCATED ON FAN STATOR
- COWL DOORS / REVERSER REMAIN ON AIRCRAFT
- EASY ACCESSIBILITY FOR INSPECTION

CF6

CF6/DC-10 PROPULSION SYSTEM

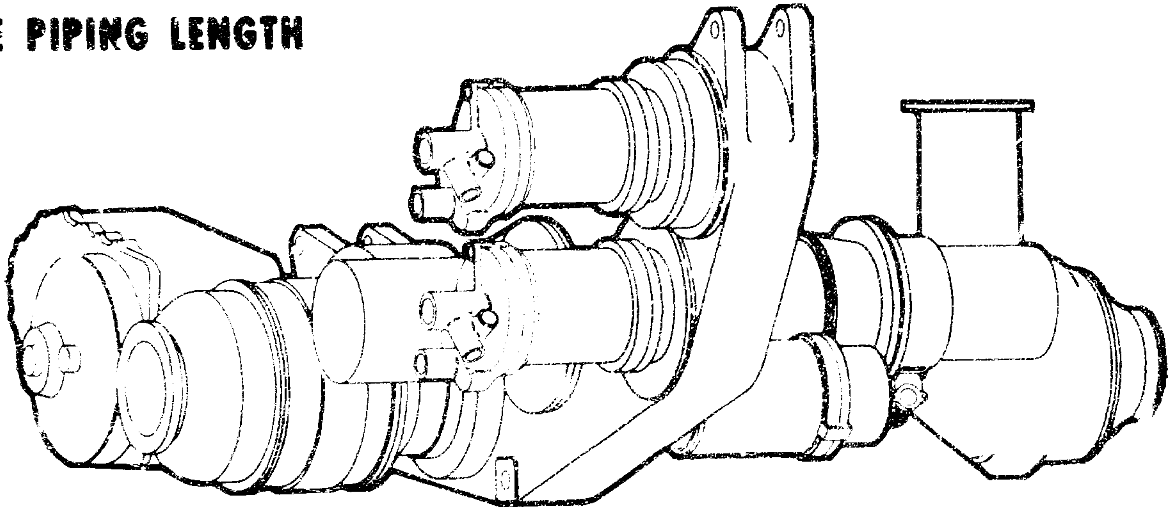


- ELAPSED TIME TO OPEN/CLOSE FAN COWL DOORS: 3.0 MINUTES
- EXPOSES 72% OF LRU'S

C76-35/7-68

ACCESSORY GEARBOX

- ACCESSORIES SPACED TO PROVIDE EASY ACCESSIBILITY
- ACCESSORIES LOCATED TO MINIMIZE PIPING LENGTH

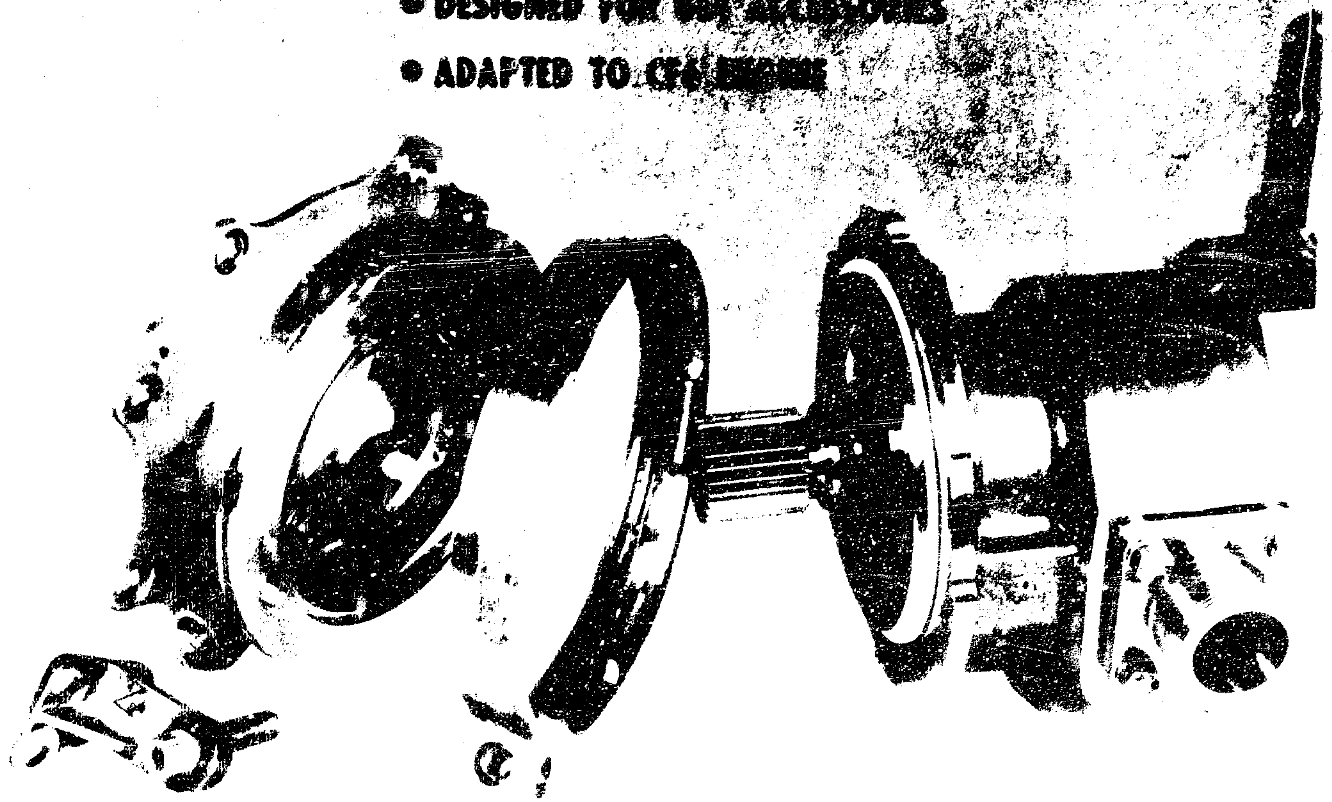


FWD LOOKING AFT

GE4 SST

QUICK ACCESSORY DISCONNECT (QAD)

- DESIGNED FOR [illegible] ACCESSORIES
- ADAPTED TO CF6 ENGINE



DESIGN FOR MINIMUM MAINTENANCE ERROR

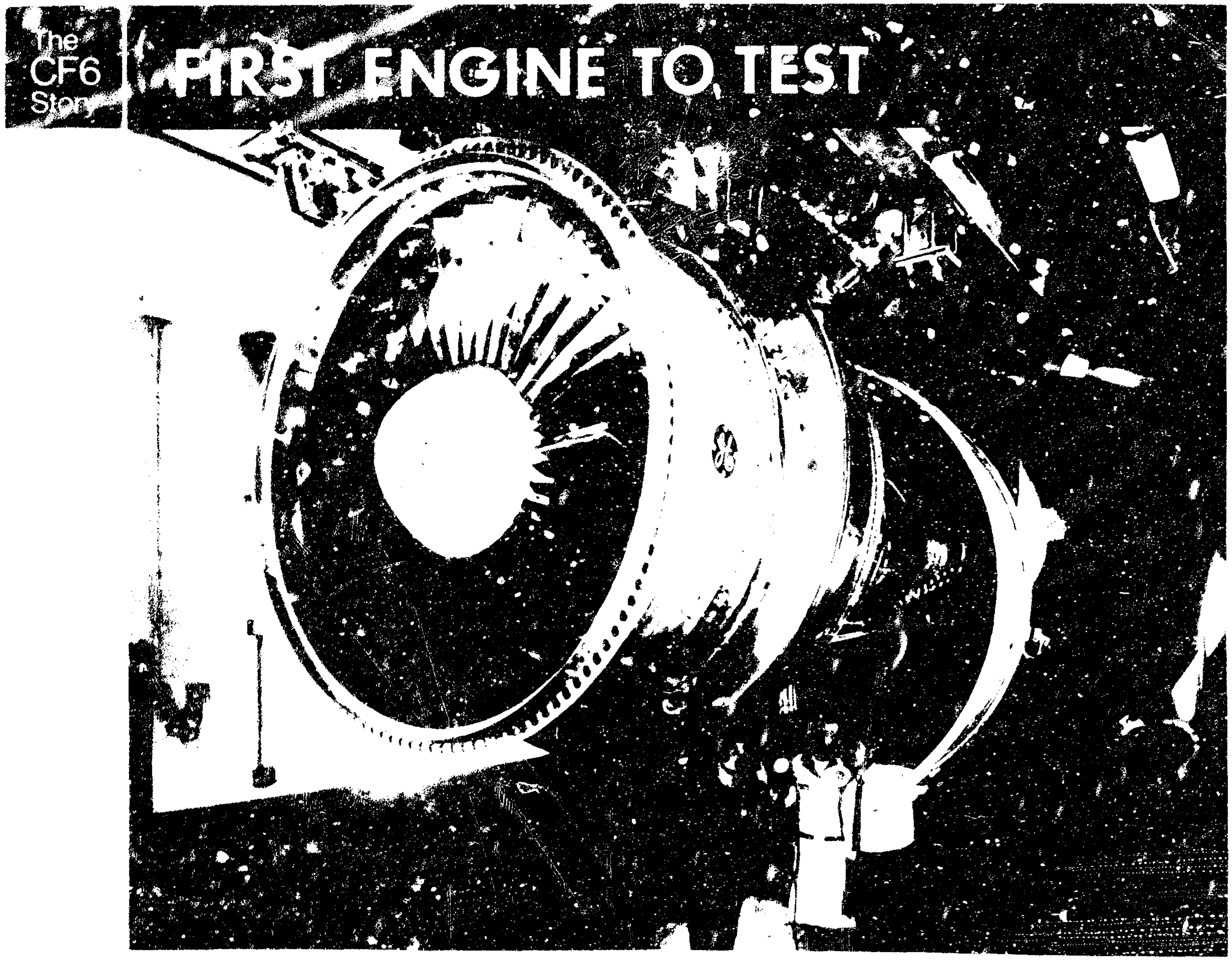
- BLADES WHICH CAN ONLY BE ASSEMBLED IN THE CORRECT LOCATION/DIRECTION
- POSITIVE RETENTION OF OUTER BEARING RACES
- AMPLE LEAD-IN CHAMFERS ON MATING PARTS
- FLUID PORTS ON ALL COMPONENTS SIZED TO PREVENT WRONG HOOKUPS
- POSITIVE BLADE RETENTION

MAXIM NO II

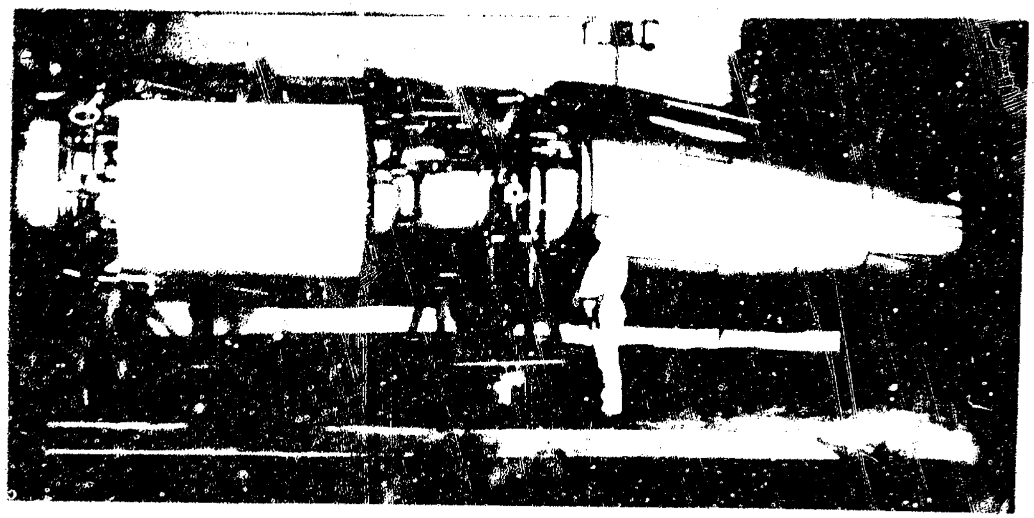
40,000 lbs thrust engines

are big unless divided into

smaller pieces

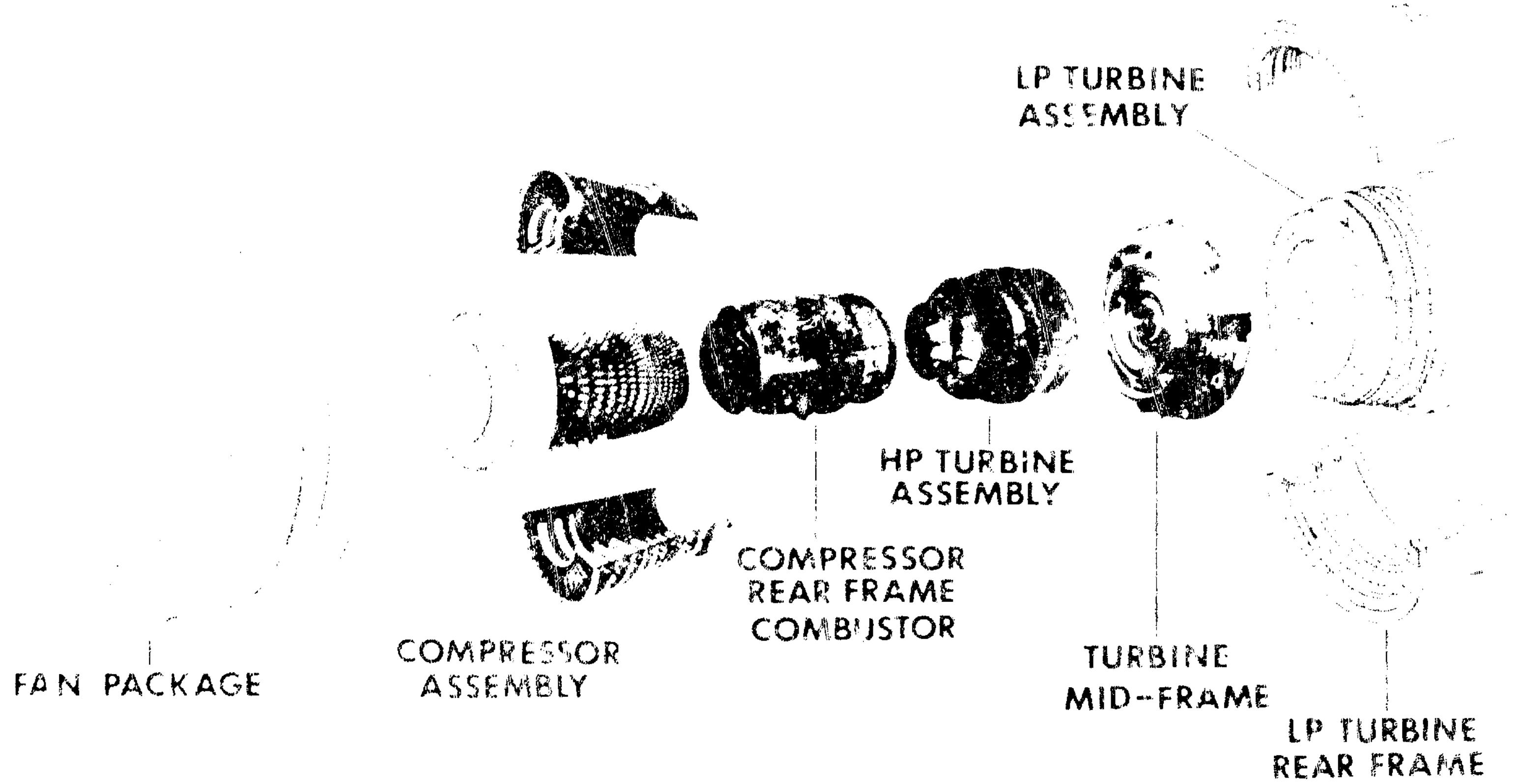

The CF6 Story
FIRST ENGINE TO TEST

GE4/SST TURBOJET MOCKUP



The CF6 Story

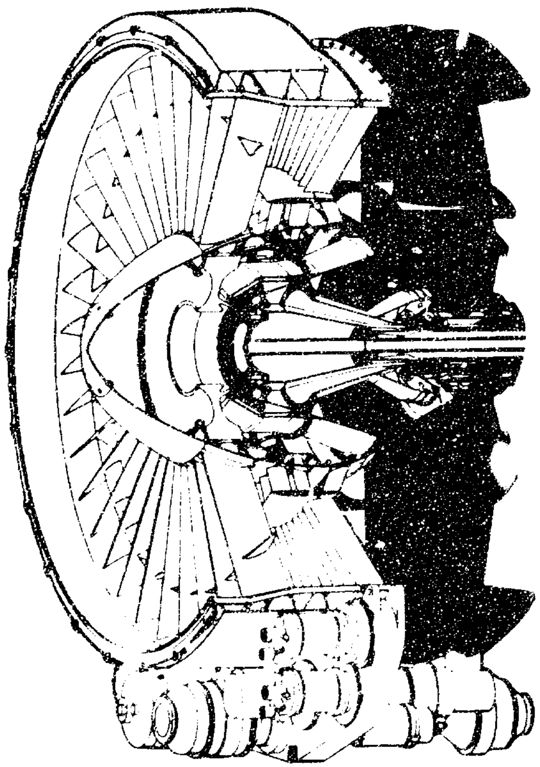
CF6 ENGINE MODULES



CF6-33 7-68

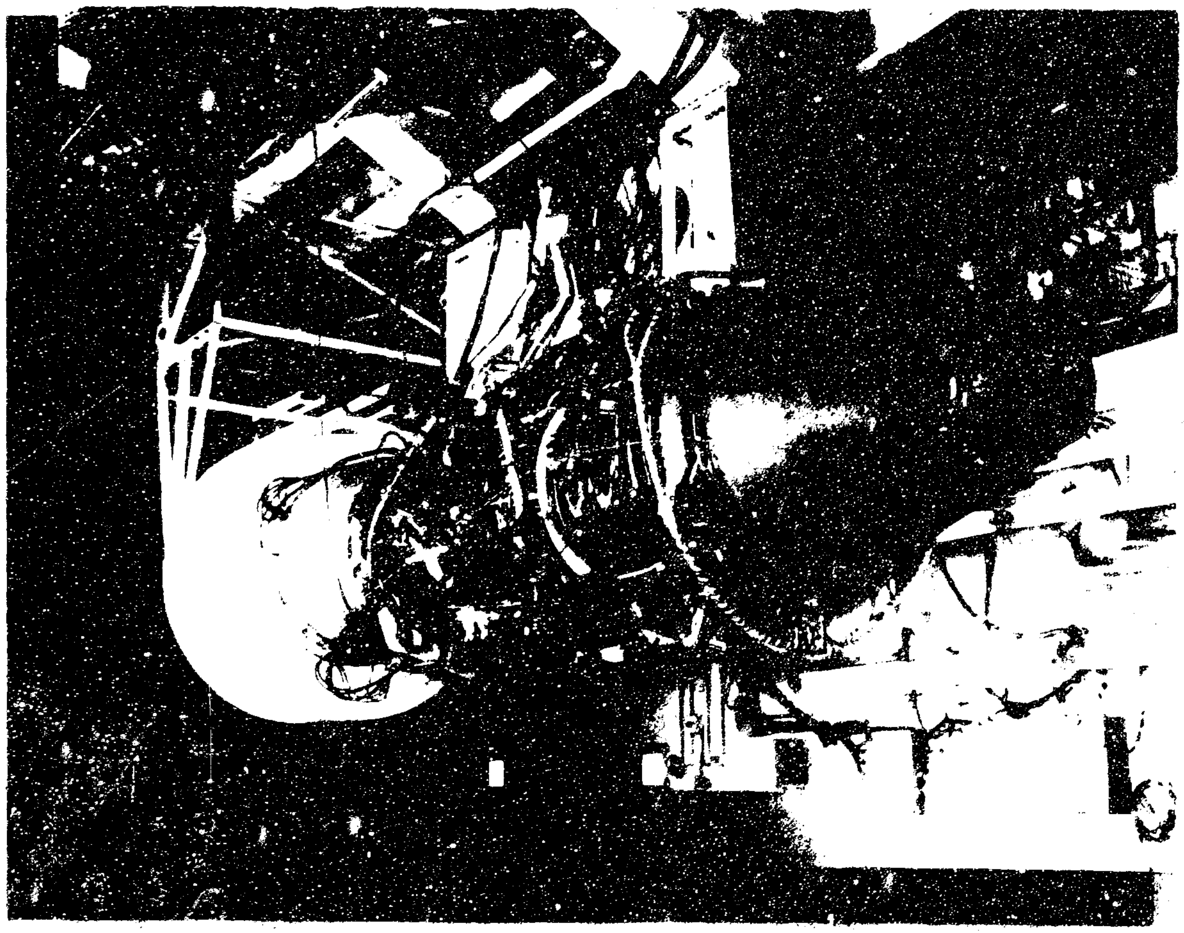
FAN FRAME

- 12 STRUTS
- DESIGNED FOR 50,000 hr
- MATERIAL PERMITS WELD REPAIR
- SUPPORTS NO.1, NO.2 AND NO.3 BEARINGS
- HOUSES POWER EXTRACTION DRIVE



SM40

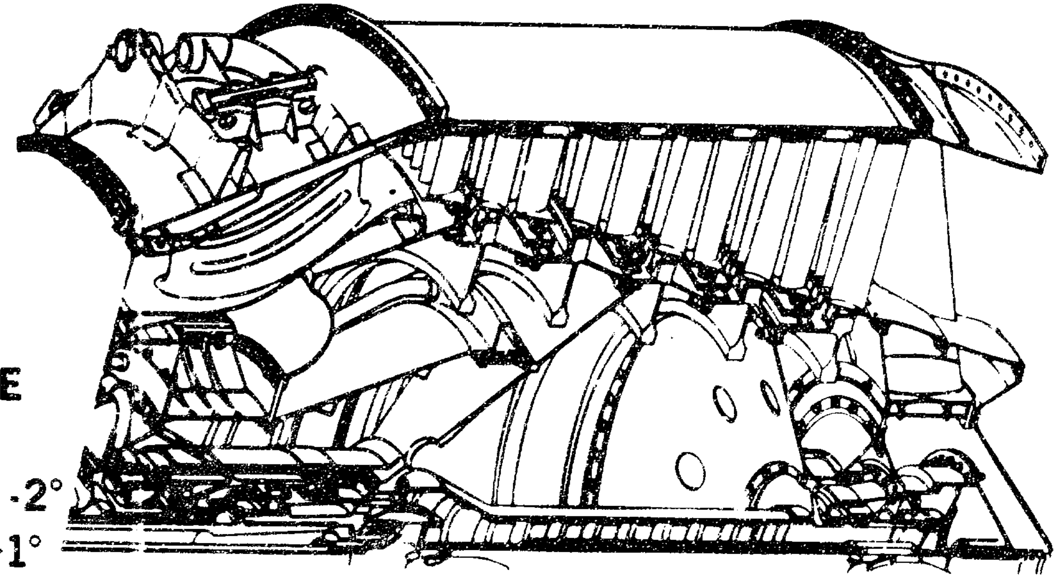
CF6/TF39 CORE ENGINE



CF6 Story

LOW PRESSURE TURBINE

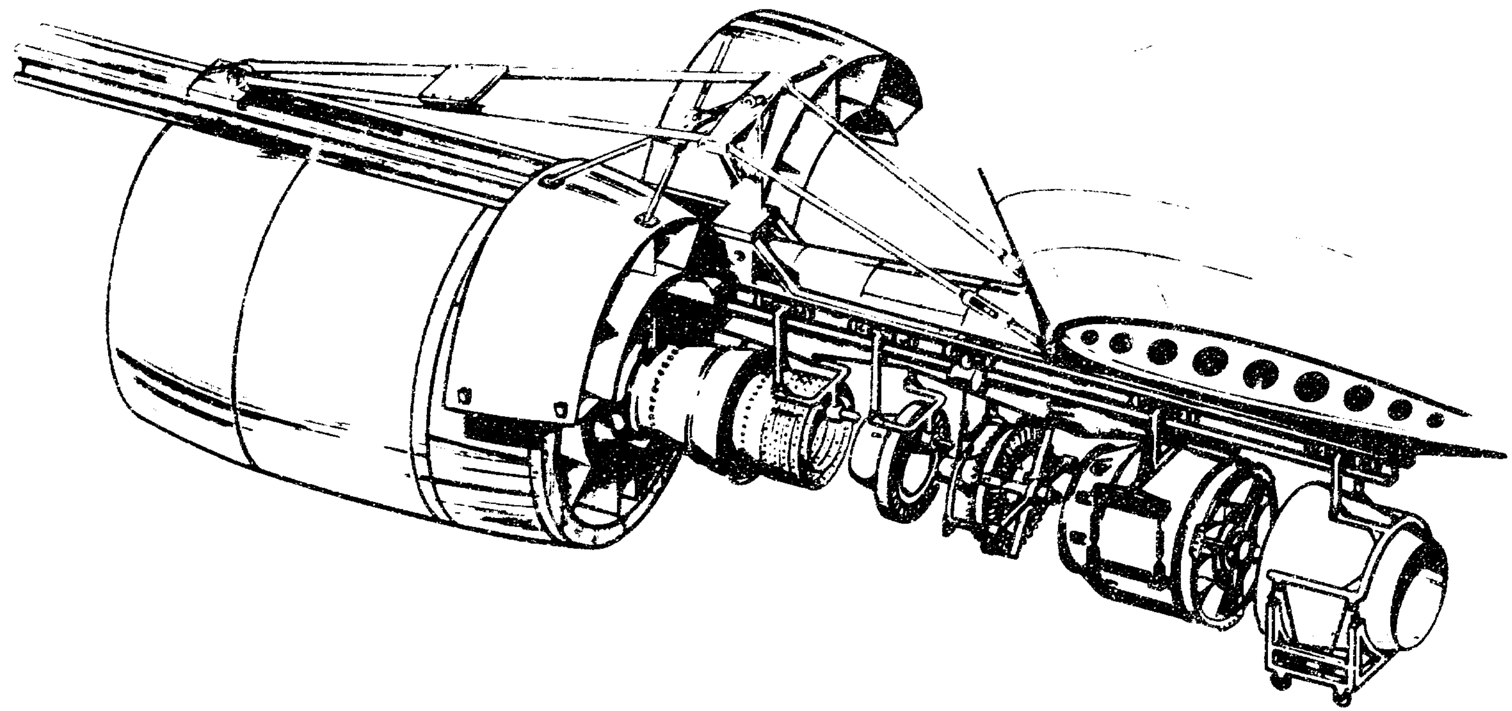
- TF39 PROVEN DESIGN
- 5 STAGE TURBINE
- LONG DESIGN LIFE
- COOLED CASING
- PROVEN PERFORMANCE
  η_t-90.7%
  EXIT SWIRL-TAKEOFF -2°
  CRUISE +1°
- MAXIMUM TURBINE INLET TEMPERATURE 1570°F



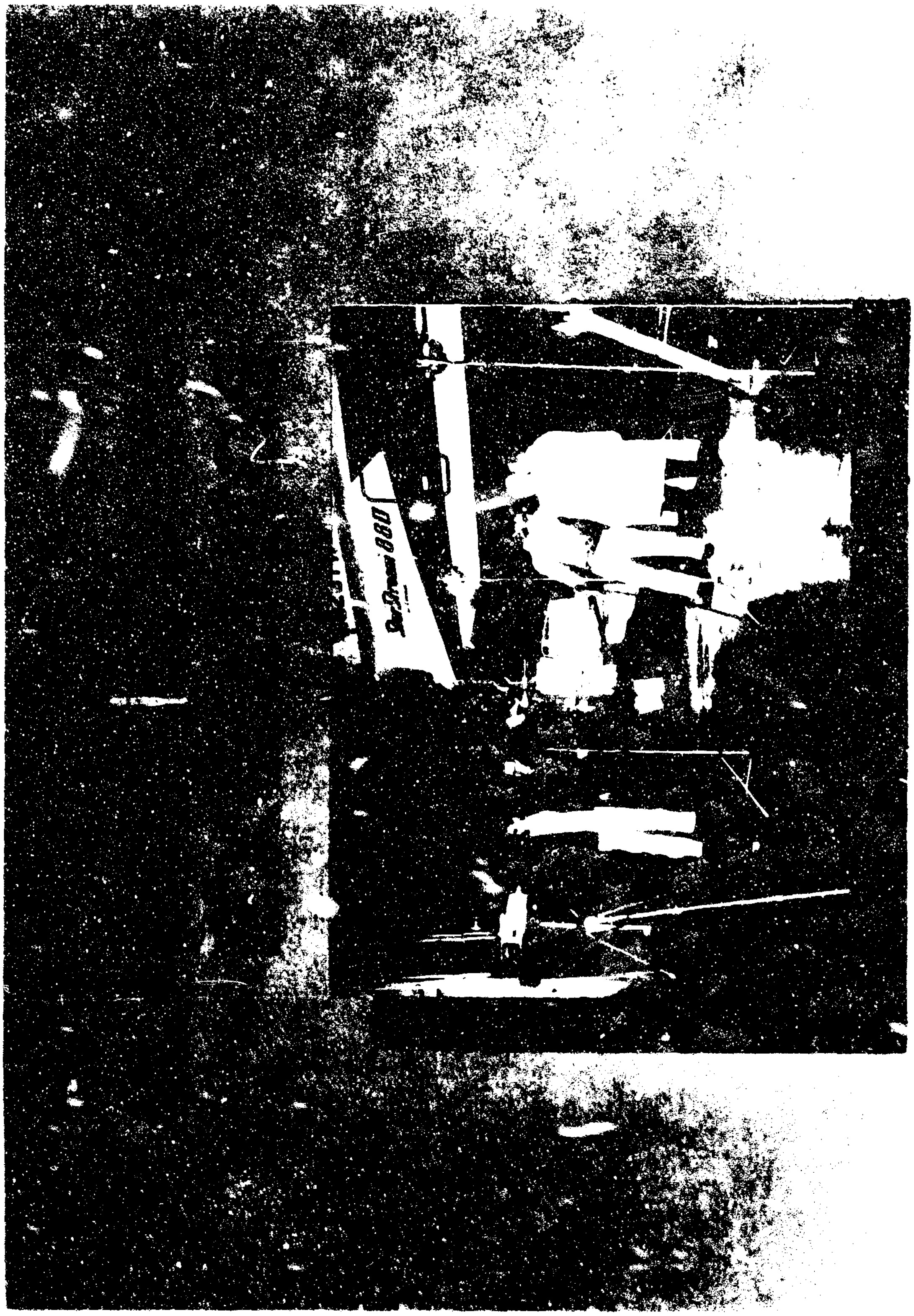
SM41

The CF6 Story

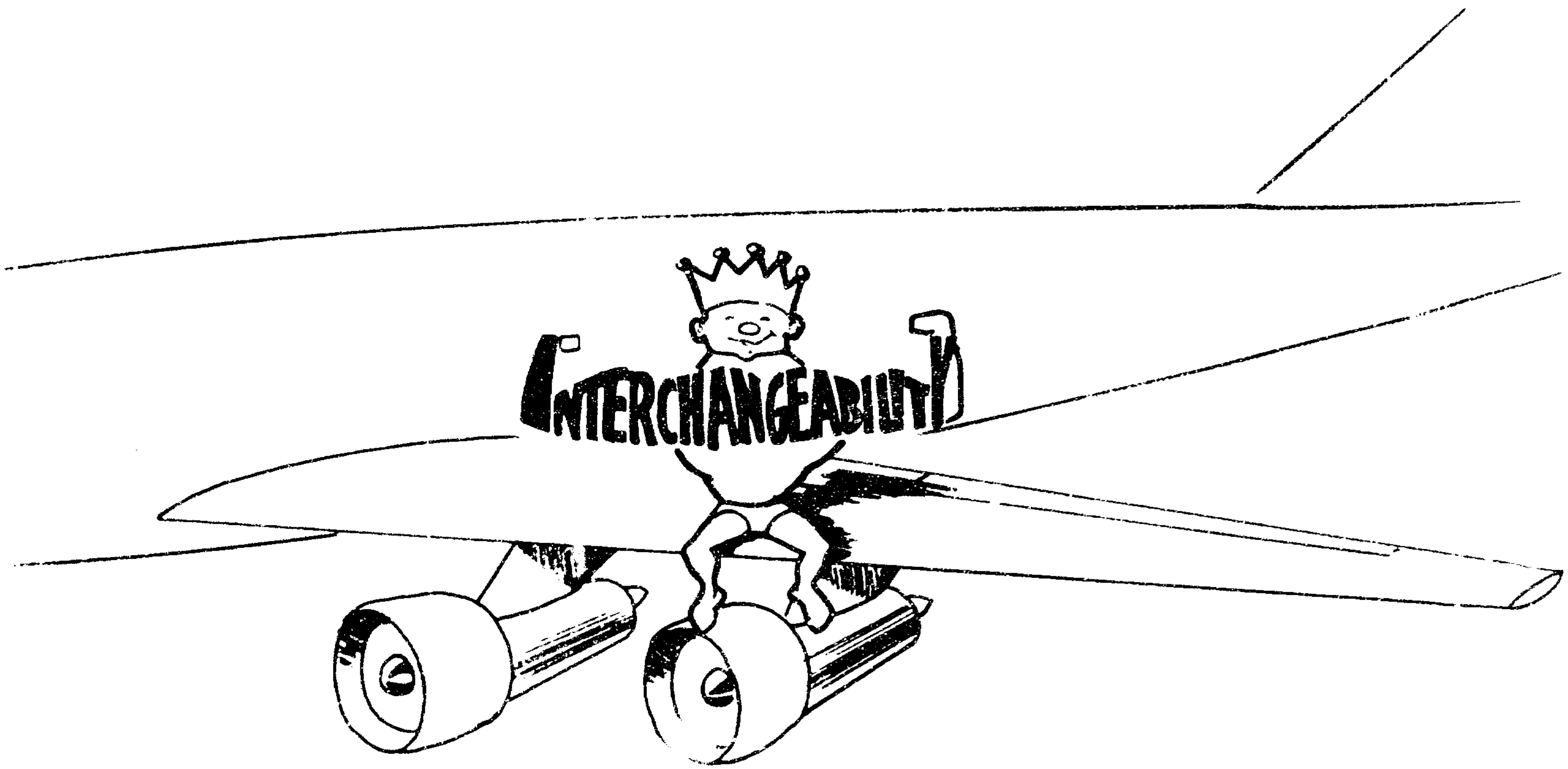
CF6 ON-WING MAINTENANCE



CF6-39 / 7-68



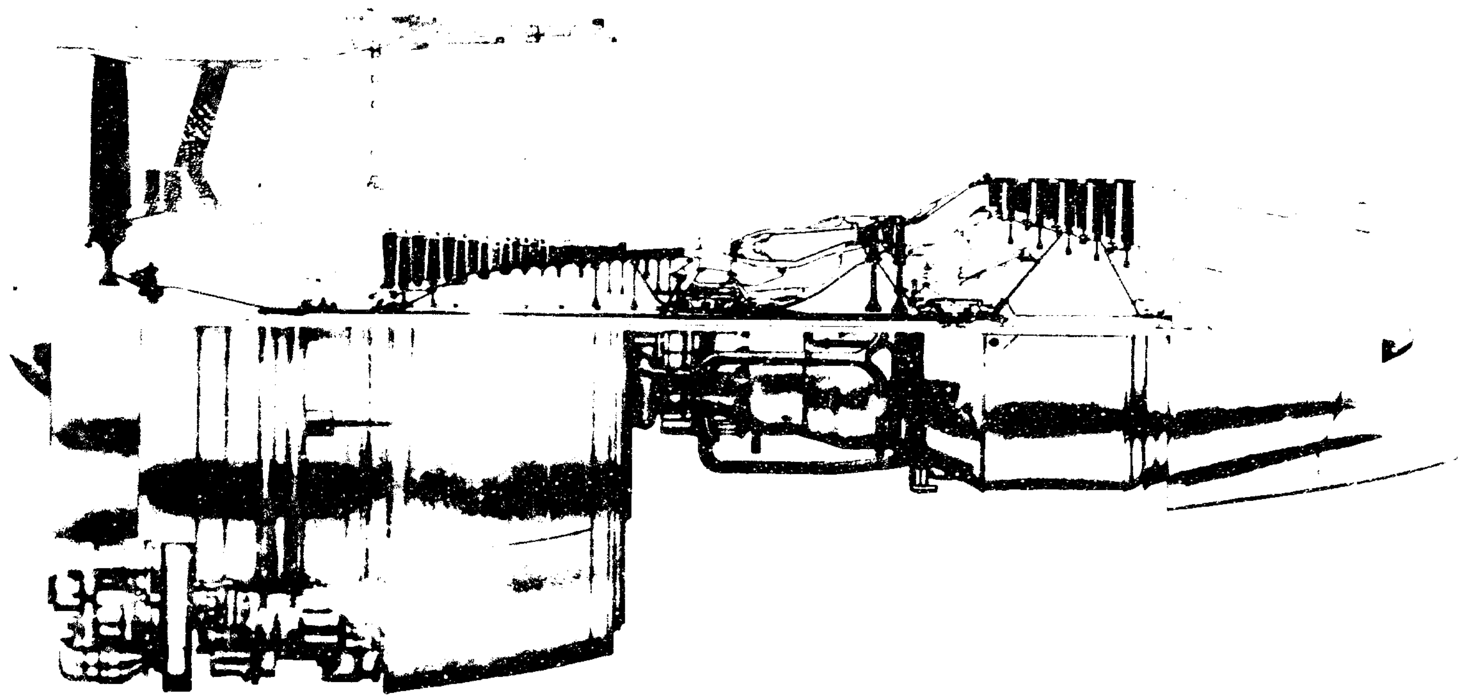
MAXIM NO III



**If modules are changed on the wing,
Interchangability is king**

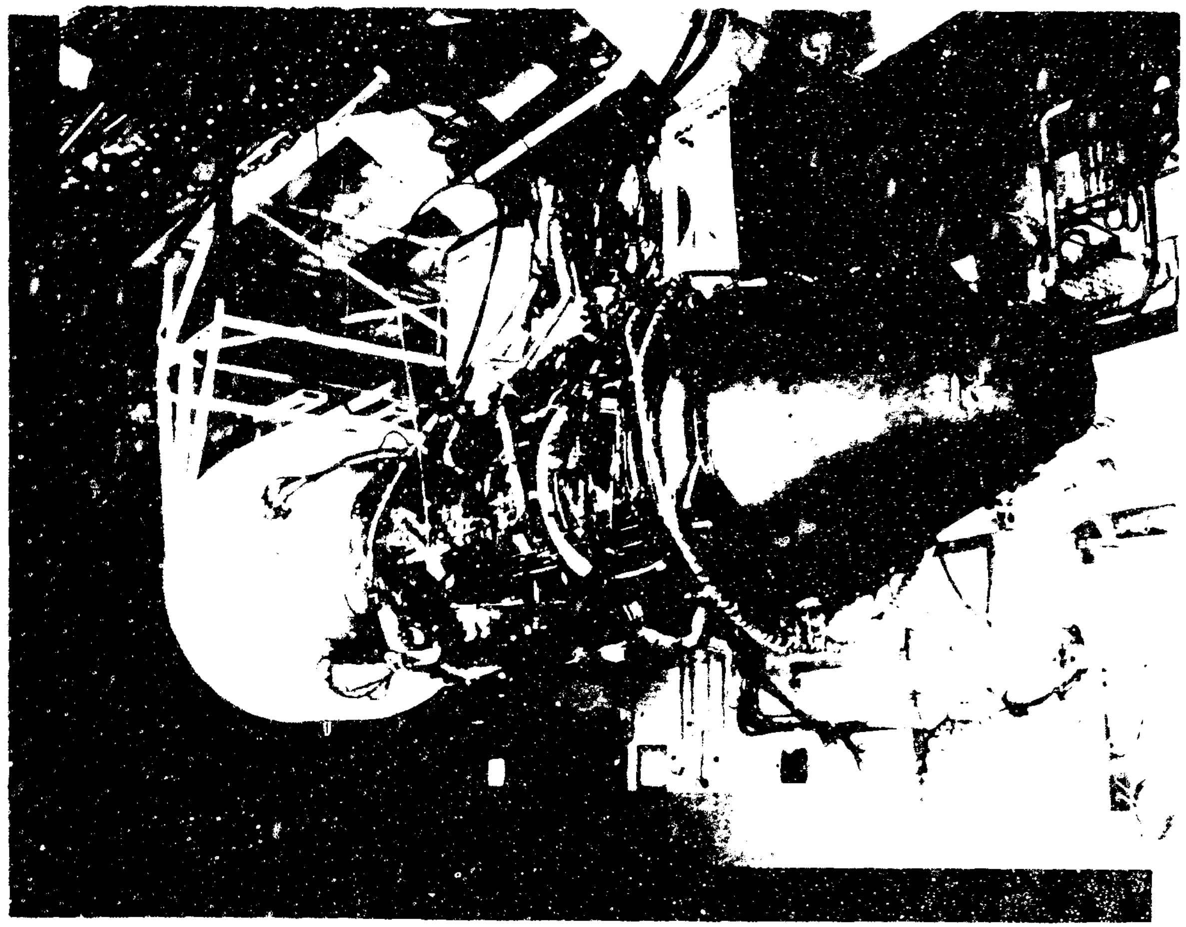
The CF6 Story

CF6 HIGH BYPASS TURBOFAN

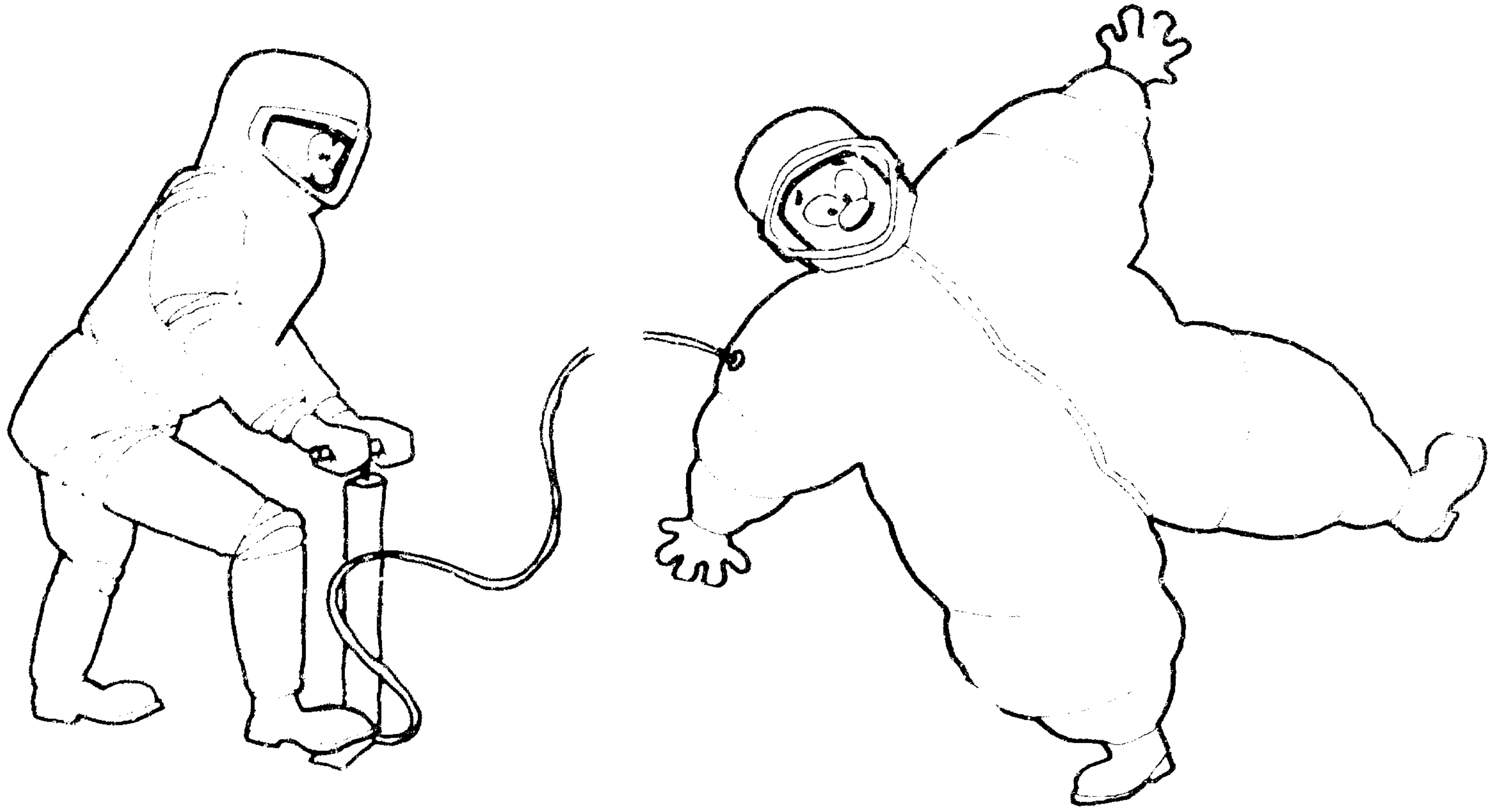


R-1
CF6-22/7-68

CF6/TF39 CORE ENGINE



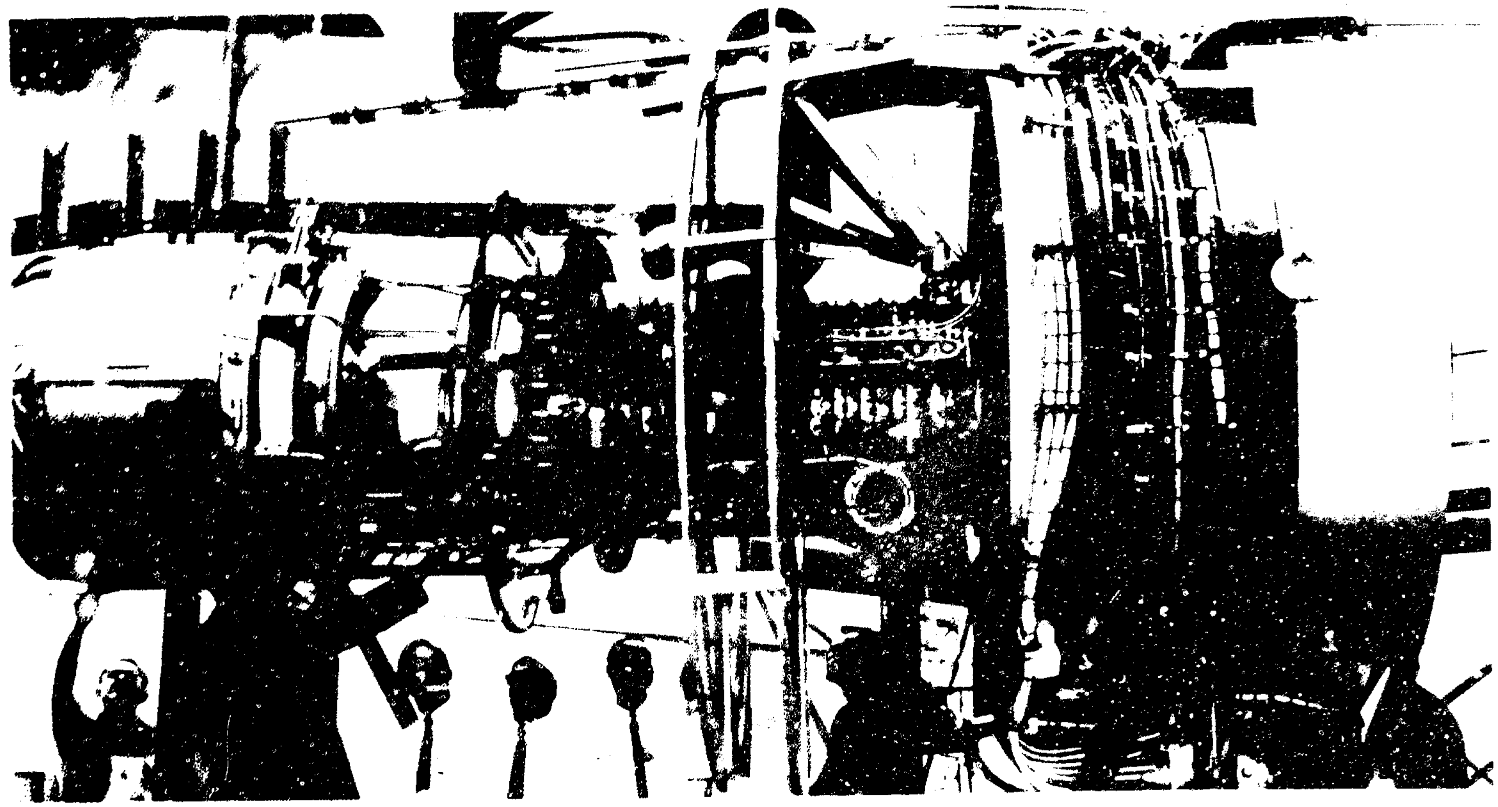
MAXIM NO IV



Even astronauts don't work in a vacuum

The CF6 Story

PROPULSION TEAM

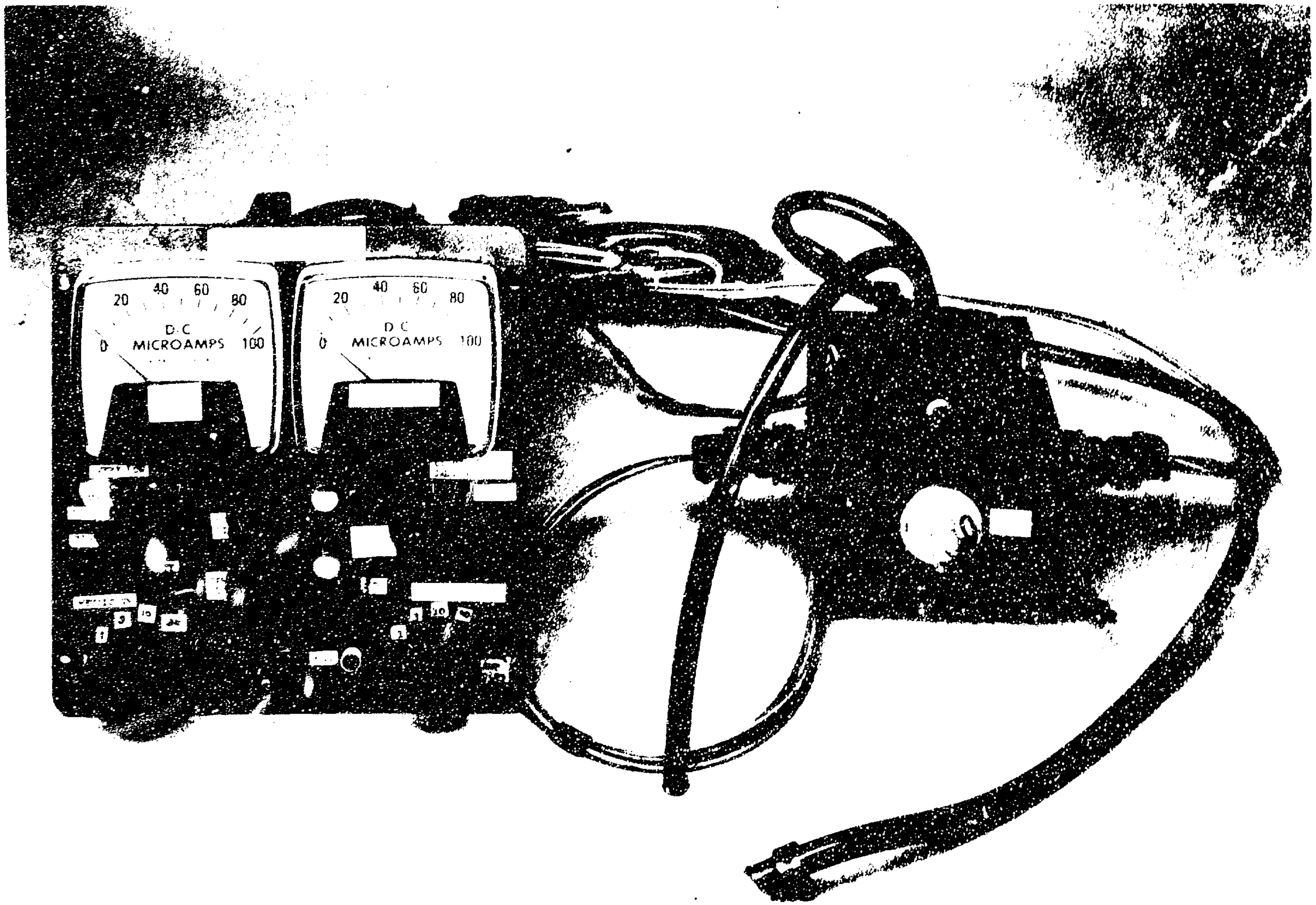


ST-11

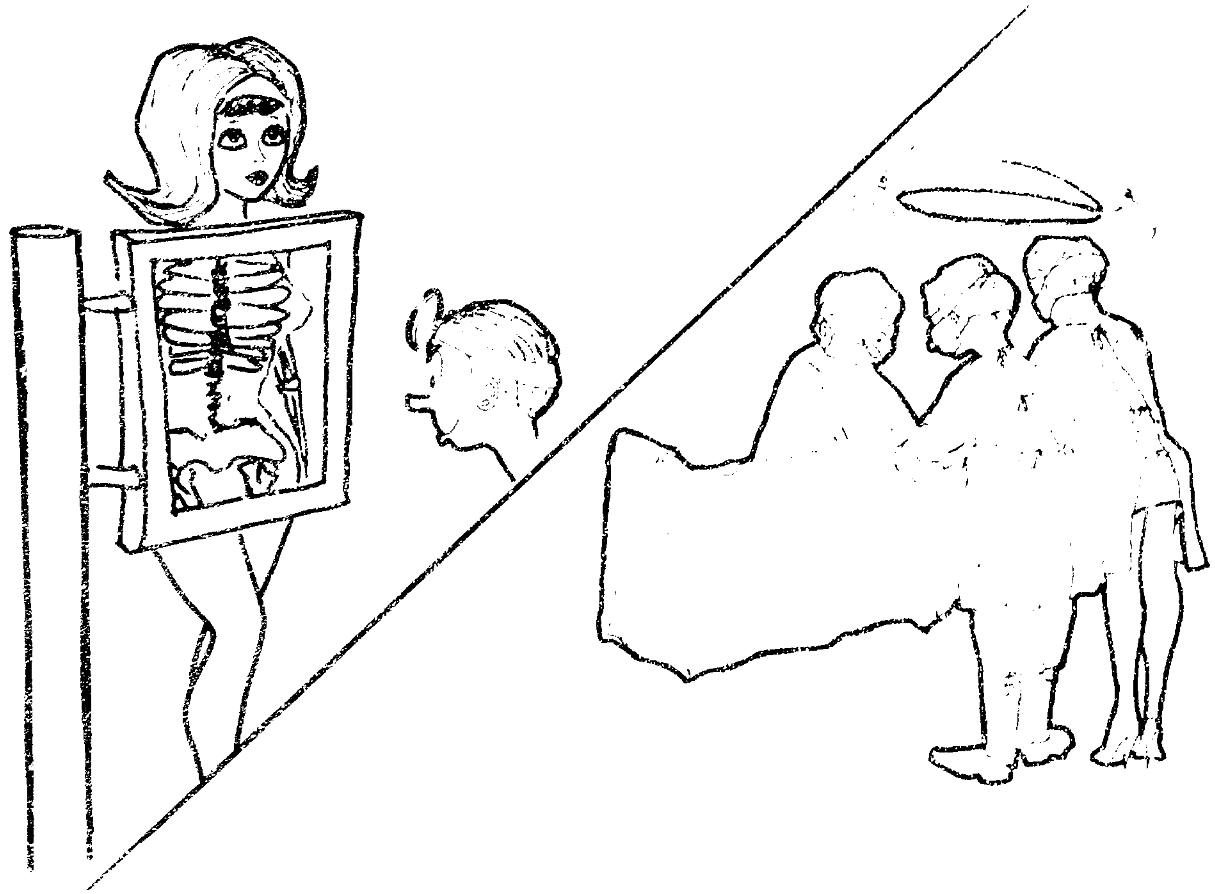
MAXIM NO V

Diagnostic equipment does not prevent, it anticipates

OIL ANALYZER

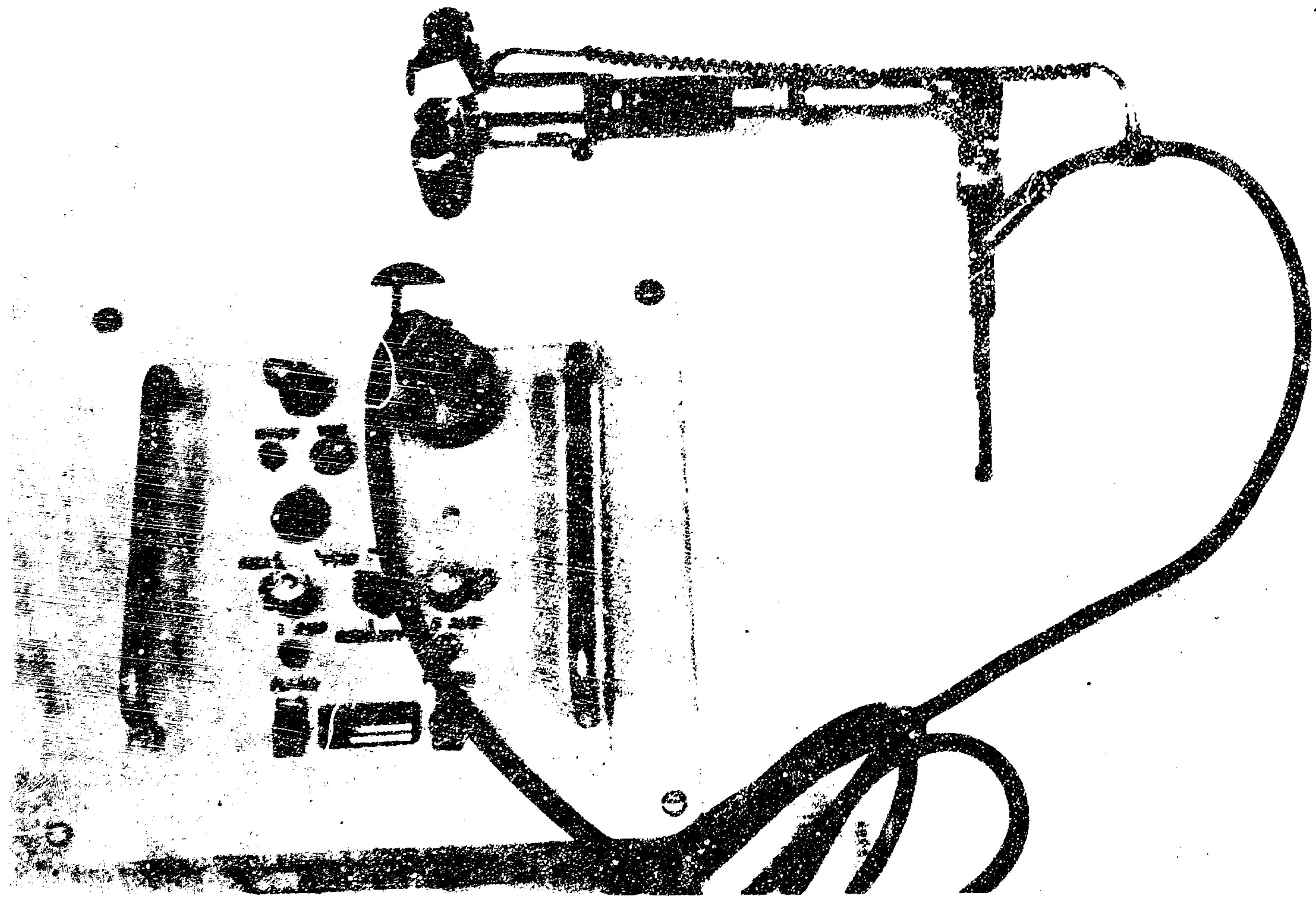


MAXIM NO VI



Looking from the outside beats the dickens out of teardown

BORESCOPE WITH 35mm CAMERA



GE4 BORESCOPE INSPECTION STUDY

(ELAPSED TIME-HOURS)

INSPECTION MODE	INTERMEDIATE INSPECTION		COMPLETE INSPECTION	
	TOTAL	ON-ENGINE	TOTAL	ON-ENGINE
1. MANUAL (EYEBALL OR TV)	4	4	4	4
2. MANUAL (TV WITH AUTO SCAN)	3	3	4	4
3. HIGH-SPEED VIDEO/MOVIE	4	3	5	3
4. HIGH-SPEED VIDEO/MOVIE WITH AUTO SCAN	3	2	4	2
5. HIGH-SPEED VIDEO/MOVIE (TWO TAPE REELS PLUS AUTO SCAN)	3	2	3	2

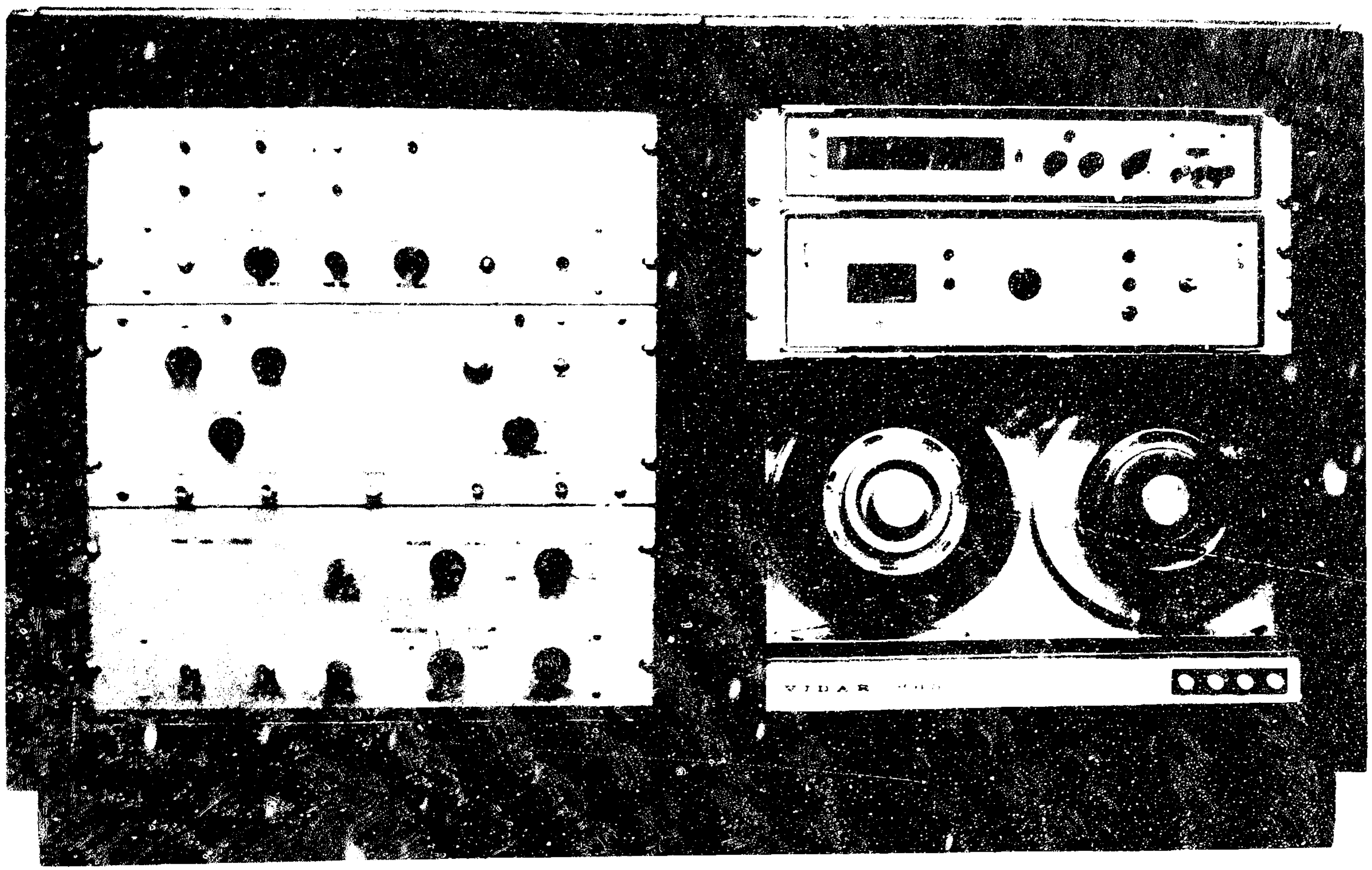
N4

The CF6 Story

IR 192 ISOTOPE RADIOGRAPH

CF6-267/8-68

DIAGNOSTIC TURBINE BLADE TEMPERATURE RADIOMETER



FMR - Field Maintenance Reliability

American Airlines, Inc.
H. L. Antosh

Air transportation has pecked its way out of the Stone Age of the industry and by use of advanced technological developments and discoveries, has emerged as one of the most complex and demanding businesses in the space-age environment. American Airlines has an aircraft landing or taking off every 35 seconds of the day - every day of the week, a fact staggering to have envisioned a few years ago.

With the advent of the new generation of aircraft - DC10 - 747 - SST - we are at the threshold of infinitely more complex operational challanges. Methods used in maintaining aircraft in an earlier state of the art are no longer adequate to assure the safe, on-time service required to keep pace with today's economy.

The philosophy "fix when it breaks" is unacceptable for effectively maintaining today's highly complex aircraft. Today's aircraft with their many complex systems necessitates a new philosophy of "fix before fault" involving a capacity to anticipate and isolate premature problem areas. In keeping with this new philosophy American Airlines has pioneered a program that presses into service all the marvels of sophisticated computer operat with the reasoning capabilities of highly qualified specialists to develop FMR - Field Maintenance Reliability.

The backbone of American Airlines' Field Maintenance Reliability Program is the multi-million dollar Sabre Center at Briarcliffe Manor, New York. The Sabre Center houses the world's largest corporation owned real-time computer system. Utilization of this facility gives us a unique advantage in our efforts to isolate problem areas in a premature condition and make a reality of the new philosophy, "Fix before Fault."

A pilot FMR program was implemented in connection with our 727 aircraft and total fleet involvement was achieved by 1 February 1968. The success of the system was such that we have ordered equipment to expand FMR to our other fleets. On 1 January 1969 the BAC 400 fleet will go on FMR. The 707 fleet will be on system 1 March 1969.

FMR is an integral part of our overall Condition Monitored Maintenance program, which has provided American with a successful preventative maintenance control. Condition Monitored Maintenance is a system for maintaining aircraft reliability which integrates Flight, Overhaul, Line Maintenance, Engineering, Production Control, Inspection and Supply in the detection, identification and solution of problems.

The flight crews are the men with their fingers on the pulsebeat of our aircraft. FMR provides us with a unique ability to collect, analyse, and react to pilot reports, from a heretofore posture of unprecedented efficiency.

Let's see FMR in action. October 31 - On American Flight 175, 727 aircraft number 990, the flight crew recorded that the number one throttle had a tendency to creep with the friction lock on. It was noted that the knob on the number one throttle was one and a half knob's length out of line in "Climb" setting. The PIREP item was entered into the FMR system. During the overnight Termination Check, maintenance cleaned and checked the friction lock. The rigging of all three throttles was checked.

Another item was also entered on the PIREP. "Nose strut bottoms on taxi." The Dallas Technical Foreman issued orders to Detroit Maintenance. "Service with oil and air, per maintenance manual - and check for air leaks around the metering rod." Detroit Maintenance also accomplished this job during the night. An FMR entry of job accomplishment was sent. At 2:11 AM the PIREP and FACT (Final Action Taken) were entered on the FMR Agent Set by Detroit.

Dallas Technical Services, fleet base for the 727's, has the capacity to call for a display for any or all systems on any or all aircraft on a regular schedule - or at will. Every discrepancy and corrective action is reported to Fleet Base Station. The Fleet Base Stations are responsible for the effective maintenance of all aircraft in a specific fleet. They are located to receive a high density of flights which provides for first-hand observation of problems - and maximum opportunity for aircraft routing to accomplish required maintenance. Fleet Base Stations assign the major maintenance packages for the aircraft in their fleet and monitor individual aircraft to assure timely correction of problems and to detect any characteristics having fleetwide significance.

Technical Foremen staff the Fleet Base Stations. With the receipt of each mechanical discrepancy reported, the Technical Foreman reviews the problem against any previous history. He also reviews the corrective action taken and decides if the action was effective. He determines any further remedial steps to be taken, if necessary. The Technical Foreman also utilizes the real-time capability of the FMR set to follow-up and direct any deferred actions that are necessary for completion at the terminating station. The Technical Foremen are the key to the effectiveness of FMR. It is their ability and experience that serves as the pivot for the FMR function. They receive and evaluate the data introduced into the system, and relay the results of their analysis to the Line Stations so that required maintenance can be accomplished.

November 2 - Aircraft 990 - Operating as Flight 342 - Detroit to Boston - Flight Crew encounters friction factor on #1 and 3 throttles. BOS Maintenance checks. BOS Maintenance - washed out lock. FMR Records - Item 27 on PIREP noted as repeat on System 70 - Power Plant.

November 2 - Aircraft 990 - Returning to DTW as Flight 175. Crew enters PIREP - No. 1 throttle friction. DTW Maintenance enters action - cleaned friction lock during termination check. Dallas - November 3 - during periodic display of FMR entries, Technical Foreman notes the problem with aircraft 990. FMR history capability provides data on the PIREPS and the action taken.

4:01 Dallas Technical Foreman instructs LGA Maintenance of action to be taken when aircraft #990 makes its T/C that night. Action to be taken - source of procedures. November 3 - While the Dallas Technical Foreman has been issuing remedial steps for aircraft #990, the flight crew on what is now Flight 426 notes a creeping throttle. At Boston - due to insufficient ground time available - Boston Maintenance has ascertained that the problem is deferrable. Boston Maintenance notified Dallas Technical Services of the action.

LaGuardia - November 4 - 3:00 AM. Maintenance notifies Dallas that they have checked the situation, and performed a follow-up check. November 5 - The Dallas Tech. Foreman determines that more action is indicated. Since the aircraft would make its next Termination Check at Dallas - the Tech. Foreman issued an order to Dallas Maintenance to have a replacement ready and to accomplish a change overnight.

The order included the part number and the maintenance manual identification. Dallas Maintenance accomplishes the job - and reports back to FMR.

Constant check on a condition and the steps being taken to control or remedy the situation provides an up-to-date monitor on the status of each system of each aircraft in each fleet.

FMR - utilizing the technological resources of man and his machines provides a unique tool for monitoring and oversight of the reliability of our aircraft. Maintenance requirements ... materials needed ... allocation of manpower. Economical utilization of available aircraft and facilities. Detail information - available on demand, and without research - all are features of FMR.

FMR utilizes the input-output equipment of American Airlines' 40 million dollar real-time seat reservation system - SABRE. It should be noted that our FMR Program utilizes the commuter lines and memory bank of our SABRE installation but Maintenance has about 30 agent sets and three Honeywell 705C rapid printers at the Fleet Base Station. The 705C unit prints out 30 times faster than the standard agent set. This facility is warranted by the tremendous amount of material required for daily analytical review on aircraft by both fleet and individual airplane.

The Agent Sets are connected by more than 31,000 miles of communications facilities to SABRE at Briarcliff Manor, New York. FMR information input to the system passes edit routines which dete any errors. The sender cannot input incorrect information. Input is stored and is available immediately upon being reported.

Current information includes all mechanical problems and corrective action taken within the last 24 hours. Pilot report ... Maintenance Repair Items ... Technical Foreman work requests. Deferred items - problems where partial action has been taken or the item has been deferred. Available for each system, each aircraft, all systems on all aircraft. History - all mechanical problems - and corrective action for aircraft and each system for the last ten days. When each flight segment terminates, the significant pilot reports are transmitted to the SABRE system. At the end of each aircraft's flying day, all PIREPS are introduced into FMR.

Within seconds after input the information can be fed back to any requesting station on the system. These items will be worked on during the night. The economical use of facilities, materials and manpower is more effectively accomplished when every discrepancy is remedied in one place during one work period. Accomplishing all open items each day is a prime objective of the system. Safety, reliability, dependability and economy are constant objectives of all facets of Maintenance and Engineering operations.

The historical output of FMR provides an aircraft and system code print-out of each discrepancy for the past ten days - on demand from the system. Additionally, a print-out each week - on a month-to-date format is produced for analysis by Fleet Base Stations and the M & E Center in Tulsa. Why? To accomplish a maintenance program that encompasses the maximum safety, reliability and economy of operation.

FMR provides a capability of detecting an imbalance in any of the following areas - a component part, a system, an aircraft, a fleet of aircraft and brings these imbalances into focus as a regularly recurring problem. Recognition of approaching problem areas in a day-to-day analysis becomes an important tool in our continued effort of premature detection of failures. In the continuing search for a safe and economical operation, in an increasingly expensive environment, the ability to expose recurring expense items that can be scrutinized ... evaluated ... and remedied, is essential. Communication is an "IN" term today.

It is obvious that programs of this stature could not be accomplished without the aid of some of the world's most complex equipment. This very sophisticated computer system, coupled with highly qualified technical specialists, provides American Airlines Maintenance Department with a tool in keeping with the demands of a business that imposes an increasingly heavy responsibility to the flying public.

Many people have participated in this effort, making it the success that it is. Our acknowledgements to the FAA for the patience they displayed during the development stages, and the American Airlines personnel involved in the long tedious hours of attention to detail that was necessary to reach the point of achievement that we are at today.

IMPROVED AIRCRAFT RELIABILITY IN EASTERN AIRLINES THROUGH TRAINING AND UPGRADING THE AIRCRAFT MECHANIC

Presented at the Federal Aviation Administration Fourth Annual Maintenance Symposium in Oklahoma City, Oklahoma December 3-5, 1968 by T. J. Tanner, Manager, Technical Training, Eastern Airlines.

I am honored that I have been asked to be a part of this panel before such an important group to talk for a few minutes on Eastern's approach to improved aircraft reliability through training and upgrading the aircraft mechanic.

First lets take a look at what the line mechanic's roll in aircraft maintenance may be, then we have the basis in setting training objectives in the areas we are looking for improvement or the proper method to be used in arriving at the end result.

A. Airworthiness of Eastern's Aircraft is maintained by carrying out the maintenance plan as covered in the FAA approved Maintenance Manual.

B. All work and inspection shall be performed by the mechanic and/or inspector as outlined in the Maintenance Manual.

C. Work or inspection is generated in the following manner:

   1. Prescribed work and/or inspection items as covered in approved Maintenance Plan. (All items below phase check)
   2. Found by self.
   3. Found or assigned by:
      a. Supervisor
      b. Lead Mechanic
      c. Inspector
      d. Technical Supervisor
      e. Field Engineer
      f. Routing
   4. Log Book item.

D. How handled

1. Determine what need be done.

2. Accomplish

3. Temporary fix

4. Deferred

5. Dispatch on minimum equipment

6. Missing parts list - relation to above

7. Watch item

8. Recording and reporting system in accordance to Maintenance Manual on 1, 2, 3, and 4.

Understanding the roll of the mechanic, the Technical Training Departments responsibilities lie in the area of developing, producing and administering training programs that will train and upgrade the mechanic. To accomplish this task we have three subdivisions in this Department which are:

1. Classroom and On-the-job Training

2. Apprenticeship and Skills Improvement

3. Video Programs Development and Production.

Under classroom and on-the-job training this could be broken down as follows:

1. Problem areas that affect component and systems reliability.

2. New aircraft or new products familiarization training.

3. Recurrent training.

PROBLEM AREAS THAT AFFECT RELIABILITY ON PRESENT FLEET

To bring about an improvement in mechanical delays and cancellations, reliability of components and systems must be improved through Engineering design, procedures and publications, methods and mechanics know how. My comments will be

held to training by the Training Department that will improve the mechanic's know how as one of the ingredients that will improve component and systems reliability.

The number one question the Training Director must answer along these lines, is what are the subjects that will be developed into a training program and what shall be the content. Through the analysis of a specific problem by Line Maintenance Supervision, Technical Support and Engineering, they determine that an increased knowledge in the description and operation of the system and its components or the proper use of test equipment and or rigging, adjustment and calibration of a component or system would increase reliability. The subject is then established.

The problem may be systemwide or local, it may be a problem on a specific type of aircraft such as the Boeing 727, or a systems problem that affects more than one type aircraft.

After the subject has been set, the next important task is to establish the specific objectives of the course and develop the course content to accomplish these objectives. The subject is assigned to an instructor whose job is to produce the training package which may include video tapes. He gathers information by talking with Technical Support personnel, Engineering, Maintenance supervision, and Reliability Engineering. From the analysis of this information he is in a position to establish the objectives that will bring about improved aircraft reliability through training and upgrading the aircraft mechanic.

As an example, Field Powerplant Engineering noted that the Electra Propeller system was causing an abnormal amount of delays and cancellations. Also components were being changed that checked out in a satisfactory manner in the shop. Looking at the Fleet Reliability Report which is really a montly report

of the Reliability Engineering Analysis Program or REAP, it is noted that we were experiencing about 12 basic failure modes per month under 70-00-01 "Personnel and Procedures".

The objectives were established and a training program was developed along with an L-188 Propeller Trouble Shooting Guide and video tapes. Then, a 30-hour training program was set up at all Electra maintenance stations and the trouble shooting guide and video tapes were used as training aids. The October Monthly Reliability report shows that the personnel and procedures mode has dropped from an average of 12 per month to an average of 3 per month. The key to a good program lies in establishing objectives that when learned by the trainee will bring his knowledge and skills to a level that will cause him to perform in a satisfactory manner.

NEW AIRCRAFT OR PRODUCTS FAMILIARIZATION TRAINING

One of the major activities in Technical Training is the training required to place a new type aircraft or a new product in service. During the next two to three years, Eastern will place in service the Giant Boeing 747, the Concorde, Lockheed 1011 Air Bus and shortly thereafter the Boeing SST, and, the way the short take-off and landing craft is performing in our Shuttle Operation, more than likely we will have a fleet of these aircraft.

What do these new aircraft mean to Eastern's Maintenance Department? One of the things it means is an increase in mechanical personnel which multiplies the work load in the Technical Training Department in developing and conducting and administering familiarization programs on each of these new type aircraft for the present mechanical force as well as the additional personnel required to handle the increased fleet of aircraft consisting of many types. It also means

that the manpower pool from which the additional mechanics will be drawn from will not contain the skilled technician that will be required to maintain and trouble shoot these highly technical and complex aircraft and their knowledge and skills must be brought up to a level that will bring about the desired reliability.

In this fast moving technological society we live in, it makes little difference how sophisticated the machinery gets or how complex the systems become, the responsibility of training these technicians must be met so the performance of these new type aircraft fall under the umbrella of an established reliability program.

Since we are operating seven different types of Jet aircraft and will be adding four different types, in fact more complex types, within the next few years, we must gear our training production toward a system that will parallel the Line Mechanics day-to-day activities. A mechanic at one of our line maintenance stations will be called on to maintain, trouble shoot and service many types of aircraft in a single day and he must be well versatile on each type. To accomplish our goals, we in the Technical Training Department feel we must change our philosophy of training from a method of developing an independent program on a specific aircraft to a "Systems Approach" for all aircraft.

What is the "Systems Approach"? The systems approach could be defined as a method in training on a specific system that has common similarities on all types of aircraft in the fleet. Here the description and operation training of the system could be developed around a "representative system" and the mechanic would have the basic knowledge of the system no matter what type aircraft he was called on to service and maintain. In fact, the description and operation portion of the Manufacturers Maintenance Manual should be keyed to this approach.

As an example, the hydraulic system on all jet aircraft we are operating are similar in having a hydraulic pressure device, pressure controlled devices, indicators and warning lights to indicate normal and/or abnormal performance and controls to cut "on" or "off" the system, and it provides controlled hydraulic pressure to a manifold in a quantity that will operate the hydraulic units on the aircraft.

The systems training on such a system would be conducted in the following manner:

1. Description and operation of the system shall be taught using a "representative jet aircraft system." The objectives shall be:
   a. Understand purpose of system.
   b. Understand description and operation of each component, accessory, controls, and indication of system.

   Note: At no time will specific aircraft be brought into this discussion.

2. Application of representative system to a specific aircraft. All aircraft shall be covered separately.

   In the event there are deviations on specific aircraft from the representative system, the representative system shall be supplemented, bringing the representative system in phase to specific aircraft system.

   The objectives shall be:
   a. Understand difference between representative system and specific system if any.
   b. Be able to operate or preflight system.
      (1) Interpret meter readings and warning signals.
      (2) Know when system performing normal and understand malfunction indication.
   c. Understand emergency procedures as related to system and be able to perform emergency steps.

d. Understand and be able to carry out maintenance manual practices as related to system.

e. Components, accessories, control, or indication:

(1) Know location and how to get to.

(2) Know how to service.

(3) Be able to remove and install.

(a) Adjust where necessary.

(b) Calibrate where necessary.

(c) Rig where necessary.

f. Minimum equipment list as related to individual unit or system.

Aircraft systems that lend themselves to the systems approach are:

A. Power Systems

1. Electrical

a. A.C. System

b. D.C. System

2. Hydraulics

3. Pneumatics

B. Integrated Flight System

1. Compass System

2. Navigation System

3. Flight Director System

4. Auto Throttle

5. Airspeed System

6. Auto Pilot System

C. Other Systems

1. Power Plant

a. Fuel System

b. Fire Detection System

c. Ignition System

d. Air Bleed System

2. Ice and Rain Protection

3. Air Conditioning and Pressurization

4. Landing Gear

a. Brake System

b. Anti-Skid

5. Fuel System

a. Fuel, De-Fuel

b. Indicating System

c. Tank Sealant

(1) Fuel Leak Limits

6. APU

Such a system lends itself very readily in developing video tapes on a fleet of aircraft that have many types. After inauguration of such a system and tapes are produced on present aircraft, developing and producing training on a new aircraft would consist of Part 2 as previously described.

Apprentice Training

Eastern has sponsored an Apprenticeship Program since the 1940's. This program is to encourage and aid in the establishment and maintenance of high standards in the craft of airline mechanics, and to improve the standards of workmanship.

The apprentices are scheduled into the shops on a 40 hour per week basis, and are considered a part of the shops production quota.

Some of the areas he will work are:

a. Removal and installation of Jet Engine Components and rigging of Engine Control Systems.

b. Repair of jet engines which lead to basic trouble shooting and repair.

c. Jet engine ground starting units.

d. All ground support equipment, such as air conditioning trucks and tow trucks.

e. Sheetmetal.

f. Aircraft Block Overhaul and Line Maintenance.

g. Electrical/Electronics

During this same period, each apprentice is required to attend two, three hour classes per week for his academic training in internal combustion engines, jet engines, hydraulics, electrical, electronics, theory of flight, and all the sciences related to aeroplanes. He will receive about 600 classroom hours of training during the first three years. At the completion of the classroom training and shop work, he is now qualified to take the Federal Aviation Agency

Aircraft and Powerplant Examinations; and upon securing a satisfactory passing grade and passing the practical test he will be given a certificate by the Federal Aviation Agency. At the completion of the three year program he will be promoted to the mechanic's classification.

The Use Of Video Tapes In Technical Training

The production and use of video tapes for training is a way of life at Eastern. I will discuss some of the reasons we are using this media. Many problems plagued Maintenance supervision in sending their mechanics to a central training facility to receive familiarization, recurrent and specialty training. These problems were:

1. Loss of man from production.
2. Not having additional personnel to temporarily assign to cover production.
3. Covering the production using overtime.
4. and many other reasons.

During the time the man was a way from his job, daily reliability suffered even though overtime and other means were used to attempt to bridge the gap.

A study was conducted to determine how the problem of removing the mechanic from production, as well as his domicile, for taining purposes could be overcome in an effective manner. The first conclusion reached was the majority of training should be taken to the station and training be conducted before or after shift work.

To accomplish the training systemwide including more that 25 maintenance stations, an audio-visual pre-recorded program was needed. The study then encompassed the various methods of audio-visual pre-precorded programs which can be broken down into three types, which are:

1. 35MM and audio synchronized system

2. 8 or 16MM movies

3. Video tapes

The study revealed that in producing as many as 50 programs per year, video tapes would be the most economical. Also, it was decided that the present personnel in the Training Department could produce video tapes as opposed to using professionals in film production. Also, the elapsed time in getting film packages put together would make the content of the training program very ineffective, as for training to be effective timing plays a very important part. Sometimes a delay in training makes it ineffective. It has been said that the video camera has done for the non-professional in making moving scenes, the same as the polaroid has done for the non-professional in making photos because immediately after making or shooting the scene the results can be checked and a retake made at that time if found necessary.

About three years ago, we produced our first video training tapes. Utilizing the video system, we preapred the complete DC-9 Familiarization Program amounting to about 12 hours tape running time. Much of this material was recorded at the Douglas Factory prior to delivery of the first DC-9.

One of the problems of presenting a training program on a new type aircraft is, the mechanical personnel servicing the new type aircraft must be trained prior to delivery. By using video equipment at the factory, live scenes were created on tape and the actual working mechanism can be demonstrated to the class. When the first aircraft arrives, the trainee has a good pictoral picture of the real thing.

Since the original impact of the DC-9 programs, many tapes have been produced on various subjects of all aircraft. We have concentrated on subjects that assist the line mechanic in his daily servicing of the aircraft. Some of the subjects covered are:

1. Engine start and taxi - a tape f[illegible] each aircraft.

2. Compass system

3. Converting a B-727 QC

4. Trip and Service Check performance

5. and many others

At this time we have produced about [illegible] hours tape running time.

We have video players/recorders and a TV monitor at all of our maintenance stations. Therefore any of the tapes produced can be used by local management in upgrading his mechanics, as well as an instructor as a training aid. At the present time, we are logging about 5,000 view hours per month by mechanics systemwide.

Earlier, I discussed with you familiarization training [illegible] ill be required to develop on the Giant Boeing 747, the British/French Concorde and the Lockheed 1011 Air Bus which will be equipped with Rolls Royce engines. The manufactur[illegible] and Eastern will devel[illegible] [illegible]duce the complete training package on video tapes. Here again we expect to take the training to the mechanic at his domicile similar to the plan used when the DC-[illegible], [illegible] QC and DC-8-61/62 were integrated into our fleet.

The manufacturers of the Lockheed 1011, Concorde and Rolls Royce engines have reacted with enthusiasm in producing video training tapes. We expect to share the know how we have learned in the production of tapes with them so we will have the best training package possible on these highly complex aircraft.

PRODUCTION INTEGRATED TRAINING

Technical training at TWA is offered to a wide range of individuals, covering many needs and activity locations. The scope of this program is reflected in the answers to who? what? and where?. "Who" includes: helpers, mechanics, inspectors, foremen, engineers, and managers. "What" includes: initial, recurrent, new aircraft, and special training. "Where" includes: regional, major station hangar-line, overhaul, shops, systemwide and international applications. The TWA Production Integrated Training (P-I-T) program covers only several elements of TWA's overall technical training program.

(Frame 1) TWA operates both domestically and internationally. The P-I-T program has been applied at major domestic stations only. Although we do have a P-I-T program at San Francisco covering station service (275 hour) checks this presentation discusses only the P-I-T applications for "C" checks (1,000 hour) at LAX, MKC, and JFK, and base overhaul checks (8,000 hour) at MCI.

(Frame 2) Before the P-I-T approach, the typical hangar-line mechanic at a major maintenance station received 80 hours of classroom initial training during his first year of employment and 40 hours of classroom recurrent training each subsequent year, except those years in which new aircraft were delivered and operated through his station in which case he usually received 80 hours of classroom new aircraft training.

Paper prepared by Parry Barnes, Manager Technical Services Training, Trans World Airlines. Paper presented at the FAA Maintenance Symposium, THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM, at Oklahoma City, December 3-5, 1968, by Eugene L. Fox, Supervisor of Training Development, Technical Services Training, Trans World Airlines.

(Frame 3) Initial classroom training for mechanics worked reasonably well as long as most of these mechanics had significant related aircraft experience. As it became necessary to hire more and more new mechanics without previous airline experience a number of problems with initial classroom training developed. Many of these newly hired mechanics had no way to relate their classroom learning to a real-life situation on the airplane. Since an entire airplane and its related systems were presented during one 40 hour classroom session there often proved to be too much to learn in too little time for inexperienced men. Becaus of shift assignments and work arrangements much of the learning was not applied for a considerable period of time. This problem was confounded by the fact that much of the learning required to perform routine tasks assigned to the mechanic could not be covered in the classroom because of limited time. The overall result of training newly hired inexperienced mechanics in the classroom was rather low learning effectiveness with resulting losses in production and time. We should emphasize that these remarks apply to the broad base knowledge requirements and task assignments of the hangar-line mechanic. On the other hand, we find initial classroom training for electrical and electronic mechanics, regardless of their experience level, to be highly effective when combined with appropriate reinforcing on-the-job training.

(Frame 4) With the P-I-T training approach the newly hired hangar-line mechanic is put to work on a routine maintenance task under the guidance of an on-the-job instructor. His work assignments follow a prescribed pattern. The work assignments are interrupted from time to time with short sessions of classroom training as the maintenance workload permits. Typically a

hangar-line mechanic spends 360 hours in the P-I-T training program, 320 hours of which he is fully productive under the direction of an on-the-job instructor, and 40 hours of which are comprised of classroom training increments spread throughout the overall 360 hour period. We found with this approach that the mechanic appreciates what he learns in the classroom and is better able to relate this learning to his work situation. The learning is spread out over a greater period of time and his experiences in the classroom tend to reinforce his work experience and vice-versa. The results of this approach are more fully applied learning, both on-the-job and in the classroom and, perhaps most encouraging of all, an observable production increase. Because much of the classroom training is conducted during slack periods, and because of the overall improved mechanic productivity this training is actually accomplished at less expense than the previous initial classroom training program.

(Frame 5) In discussing the features of this program we will compare the program being conducted in the field at LAX, MKC, and JFK where the major work involves "C" checks and related line operations with the P-I-T program being conducted at the MCI overhaul base. In comparing both programs we will discuss objectives, planning, problems, solutions, and results.

(Frame 6) The overall objective of our field (LAX, 707, 880 -- MKC, DC9, 727 -- JFK, international 707) P-I-T program is to accommodate the necessity of hiring many new mechanics with lower experience levels. The key sub-objectives are to develop knowledgeable and capable mechanics during the

probationary period (six months) while at the same time improving new mechanic productivity and promoting proper work performance without increasing training cost.

(Frame 7) One of the more interesting aspects of the production integrated training approach is what we call the P-I-T/classroom tradeoff. In the normal classroom situation, if we assume a student/instructor ratio of four to one, we have five men in a non-productive status. For the sake of comparison we can ssume that the average cost of one man week is $200, and that the cost of five men in a classroom for one week is $1,000. If we look at these same five men in a P-I-T situation we find that only the instructor is non-productive while the four student mechanics are fully productive. Since the students are, in effect, earning their way the average training cost for this mode of instruction is $200 per week. If the logic of this comparison is valid, then we can say that one week of classroom training will pay for five weeks of P-I-T training.

(Frame 8) The planning requirements of the field P-I-T program centered on determining the instructional emphasis and mix, providing for instructor selection development, developing work assignment procedures, and creating appropriate training records.

Since most new mechanics at major field stations report to work on the graveyard shift and perform the routine portion of the check "C" operation, the instructional emphasis is centered on routine work tasks normally performed on check "C"s. The flow of new mechanics is usually from the check "C"

work towards lesser checks performed at the hangar or at various gate positions. For this reason the instructional mix also included normally accomplished routine line work assignments.

We were most furtunate in the area of instructor selection and development because of the large number of experienced mechanics we had to choose from. Newly selected P-I-T instructors were further developed through the means of classroom instruction, on-the-job-coaching by existing training instructors and training supervisors, special instructor orientation sessions held at MCI, and by cross-training each other.

Work assignment procedures had to be developed to meet three requirements. First we had to consider the flow of new mechanics into the check "C" operation. It was necessary to pace the various learning experiences so as not to create a bottleneck that would have caused the accumulation of new mechanics along several points on the learning path.

Secondly, we took into consideration the production requirements of the check "C" itself because part of the total objective was to increase new mechanic productivity on the check "C" operation. Since the routine part of the check "C" operation is controlled by task assignments called out on "work cards" we found the "work card" to be an effective device around which we would build the desired learning experience.

The third factor we considered in determining work assignment procedures involved the necessary learning requirements. We analyzed each of the "work cards" for significant learning experiences. In this way we were able to identify those critical learning tasks and direct the emphasis of the job instruction and coaching towards the more critical tasks rather than at the overall routine work requirements.

We tied all three considerations involved in planning work assignment procedures together by means of our training records. We developed simple, usually one page, instructor work sheets. An individual work sheet was used for each new mechanic. For example, the instructor work sheet used at Los Angeles covers check "C" operations, routine station services, and line assignments on 707 and 880 model aircraft. This training record calls out the "work card" assignments a new mechanic is expected to accomplish as he flows through the planned learning experience.

(Frame 9) Even with carefully laid plans a number of challenging problems developed as we began to implement the field program. One problem involved coordinating on-the-job training efforts with the maintenance production organization. In order to have a planned learning experience it was necessary for the P-I-T instructors to influence the assignment of new mechanics to various work tasks. At first this was regarded as another factor limiting the flexibility of production people in accomplishing their work. We took the approach of selling our ideas and using friendly persuasion to win the required degree of cooperation. Later as more mechanics became involved in this program and the production

people could sense the productivity improvements they became more eager partners in our work planning efforts.

It took some time for us to gain enough experience to properly balance the amount of time required for the various parts of the planned learning experience. Looking back on it, we believe the only way to resolve this problem is through the cut-and-try approach. Our experience leads us to believe that this problem is not really subject to solution by precise planning.

Integrating classroom training, surprisingly enough, also proved to be a challenging problem. We became so involved with the on-the-job training portion of the P-I-T approach that at some stations we tended to under emphasize the required elements of classroom training. Basically we use the classroom training elements to present the conceptual aspects of the various aircraft systems while we use on-the-job training to show the actual location of system components and to teach the required skills to perform assigned maintenance tasks. The various field stations chose different methods of integrating classroom training. The method they use depends largely on the nature of their maintenance workload.

Because of the rate of flow of new mechanics into the major field stations we found that a number of these mechanics were moving to other maintenance assignments before they could complete their check "C" oriented learning cycle on the graveyard shift where the primary P-I-T instructor coverage was centered. After examining a number of approaches to this problem we found the only

practical approach was to extend instructor coverage to other maintenance areas on the graveyard and twilight shifts.

(Frame 10) Basically the solutions to the various problems we found in implementing the field program were developed by adopting a problem solving and experimental approach. Although each major station had its own separate training problem and maintenance workload requirement we found many common problems and solutions in the various idea exchanges held during the program implementation phase. When we added our first P-I-T instructors we purposely stayed on the thin side in order to attain our training cost objectives. In some cases, however, the maintenance workload and new mechanic shift spread required additional instructors to accomplish all objectives.

We achieved support and cooperation from maintenance production management people by making a concerted effort to communicate the nature and extent of our mutual productivity objectives, by involving them in our planning and implementation considerations, and by collecting and analyzing enough data to demonstrate that the P-I-T program was significantly and favorably affecting new mechanic productivity and, therefore, overall maintenance productivity.

(Frame 11) The key results of the field P-I-T program were in the areas of developing proper work habits, contributing to lower mechanic turnover, reducing training costs, and contributing to higher productivity through less manhours per maintenance operation. In general, the feedback we have indicates that the field program has attained the objectives we identified as necessary

requirements at the outset of the program.

(Frame 12) Before we discuss the P-I-T program at TWA's MCI overhaul base perhaps it would be well to compare the training requirements in the major field station situation with those of the overhaul base situation. In the field P-I-T training is aimed at stations (LAX-MKC-JFK) which service primarily one or two types of aircraft. At the overhaul base all four major types of TWA aircraft (880, 707, 727, and DC 9) must be covered. It should be noted that within the 707 aircraft type classification we have both turbojet and turbofan power plants, passenger and cargo interiors, and both domestic and international configurations. In the case of the 727 aircraft type classification, we have the original 100 series, or short body aircraft, the QC (cargo/passenger) configuration, and the "stretch", or 200 series version. In short, that's a lot of possible overhaul airplane configurations. In the field the major emphasis is directed at check "B" work (station service) (approximately 70 manhours) or check "C" work (approximately 575 manhours) while at the overhaul base the training emphasis is aimed at check "D" work (approximately 23,000 manhours including related shop support). In the field we usually have one check working while at the overhaul base we normally have three or four checks working. In the field the primary P-I-T work is on the routine portion of the check while by the very nature of base overhaul work the major emphasis of P-I-T work involves non-routine tasks. In the field we cover one or two shifts with P-I-T instructors while at the overhaul base, depending on the work schedule, it is necessary to provide two or three shift coverage.

In the field we primarily cover one mechanic specialty (hangar-line), while at the overhaul base we cover nine mechanic specialties (aircraft, hydraulic, hangar metal, fuel tank, shop metal, electrical, radio, instrument, and line.) I think you would agree that the magnitude of the P-I-T challenge at TWA's MCI overhaul base is many times that of the challenge at the major field stations. For this reason there are a number of significant differences in the approach at the overhaul base as compared to the approach in the field.

(Frame 13) The overall objective of the overhaul base program was to accommodate the necessity of hiring more new mechanics with lower experience levels. The key sub-objectives were to improve new mechanic productivity, to contribute to lower mechanic turnover, to promote proper work performance, and reduce training cost.

(Frame 14) The initial planning approach was similar, in general, to the approach taken in the field. Planning requirements involved determining the instructural emphasis and mix, providing for instructor selection and development, developing work assignment procedures, and creating appropriate training records.

(Frame 15) The problems at the overhaul base were very much different than those in the field. Some of the key problems were in the areas of providing continuity of instruction, achieving a planned rather than a random approach, coordinating the training effort with the production effort, and in general, being perceived as helpful in the eyes of the production management people. Because

of the flexible nature of work assignment practices in the overhaul operation a new mechanic is likely to be moved about from one aircraft type overhaul operation to another, especially during his first year of employment. Because of the constant movement of new mechanics from one aircraft type to another we found it difficult to achieve any continuity of instruction.

In the initial approach we planned to organize the training by specific aircraft type but we found that achieving a planned rather than a random approach was almost impossible. Factors contributing to difficulty in achieving a planned approach were the movement of mechanics, variations in aircraft overhaul schedules, and the prevailing overhaul work practice of assigning new mechanics to low order skill tasks on a repetitive basis.

Because the overhaul operation involves many more mechanic specialties, many more maintenance foremen, a much broader scope of work, and work practices inconsistent with effective training by aircraft type, we found that coordination with production management people was a significantly greater challenge in the overhaul operation than at the major field stations. In general, the key problem was to find a way in which to conduct the overhaul base training that would produce the kind of productivity contribution that would cause us to be seen as helpful in the eyes of the overhaul production management people. We found that if we could achieve this goal via training we would also be accomplishing all the objectives of the overhaul base P-I-F program.

(Frame 16) The major solution we developed in the F-I-T training program at the overhaul base was to back away from planning and conducting mechanic training on the basis of specific maintenance tasks performed by aircraft type and to develop methods of identifying mechanic learning requirements in what we call basic skills and critical skills approaches. Briefly, we analyzed the work performed by each mechanic specialty. We asked ourselves the question "What basic skills possessed by a mechanic is this specialty, in our overhaul setting, would allow him to perform all of the routine and much of the non-routine maintenance tasks assigned to this specialty?" In each of the nine mechanic classifications we identified the major elements of these basic skills as well as calling out a number of sub-elements for definition purposes. For example, in the TWA overhaul hydraulic mechanic specialty, the sixteen major basic skill elements are: cable swedging-cable identification-cable installation-terminals, fittings, and turn barrels-lubrication-torque wrenches-tools-basic blueprint reading-protractors-proper manual usage-correct method of handling removed aircraft parts-seals and sealants-corrosion removal and treatment-fasteners-test equipment-and safety precautions around aircraft. After we identified the basic skills in each mechanic specialty we then structured the training emphasis, both on-the-job, and in the classroom, towards the qualification of each new mechanic over the full range of basic skill requirements in his specialty.

While we found that the basic skills approach worked well we also found that it did not go far enough. In analyzing the maintenance tasks performed we found a significant number of critical tasks that have special mechanic knowledge and experience requirements (critical skills) before they can be

efficiently mastered. Although individually, they constitute a relatively minor portion of the overall maintenance work they must necessarily be performed both satisfactorily and on time if the overhaul operation is to proceed in an optimum way. For each of seven mechanic specialties including: aircraft, hydraulic, hangar metal, fuel tank, radio, electrical, and instrument, we identified these significant critical skills. For example, in the aircraft mechanic specialty we identified the following critical skill requirements:

R & I Stabilizer Actuator & Rig

Stabilizer Cable Change

R & I Stabilizer Pivot Bolts & Bearings

R & I Elevators

Friction Test Elevator Balance Panels

Rig Elevators

R & I Rudder

Rig Rudder

Friction Test Rudder Balance Panels

Fuel Flow Check

Change Fuel Valves

Galley Water System Check

Water System Check

Flow Check HRD System

Install HRD Bottles

Air Leak HRD System

Change Auto Thrust Cables

Auto Thrust Installation and Rig

R & I Bottle Bolts

R & I Doors

Rig Doors

(R & I = Remove and Install)

The overhaul production management people were quick to see the real commercial value of expanding their inventory of critical skills. Past experience had indicated to them that the very nature of these critical skills also led to critical events. By increasing the number of mechanics qualified to perform the various critical overhaul tasks the critical skills training approach has proved to be particularly helpful when various tasks requiring these skills extend into periods not normally covered by the most experienced mechanic work force.

In many ways the critical skills training approach proved to be the catalyst for achieving the support and the kind of cooperation we needed from the overhaul production management people to attain our mutual training objectives. Since basic skill development is prerequisite to critical skill development their enthusiasm for an increased inventory of critical skills was telegraphed back through the learning process to support the development of basic skills in new mechanics. I think in all fairness we can say that we have achieved an approach in the overhaul base P-I-T program that is truly perceived as

being helpful in the eyes of the overhaul production management people. They now view these training efforts and objectives as mutually supportive, and they are providing us the kind of scheduling and work assignment assistance that our efforts require to be effective.

(Frame 17) The significant results of TWA's production integrated training program at the MCI overhaul base are the development of proper work habits, a contribution to lower mechanic turnover, reduced training costs, increased basic skill levels, increased critical skill levels, and increased mechanic productivity. In general, I think you would agree that these results have achieved the overall objectives for which the P-I-T training program at the overhaul base was intended.

(Frame 18) When we look at the problems at the major field stations and at the overhaul base that the P-I-T program was designed to overcome, a review of the overall problem indicates several key problem elements. The problem was characterized by increasing numbers of newly hired mechanics with lower levels of skills and experience, the non-productive characteristics of initial classroom training, the fact that the learning gained in initial classroom training was not being fully applied, a resulting drag on experienced personnel trying to do their own work and yet guide the efforts of these newly hired mechanics, with the overall result being that most of these newly hired mechanics were increasing their performance on the basis of a very gradual learning curve.

(Frame 19) In reviewing the solutions we developed to solve the problems in the field and the problems at the overhaul base, we find that these solutions have much in common. The key elements of the basic solution we developed include: trading off initial classroom training for more O-J-T, sequencing the work-training experience, organizing planned skill training experience, mixing increments of classroom training with O-J-T (as opposed to concentrating the classroom training in packages of forty hours) and achieving the cooperation and support of the maintenance production management organization to make the work experience of new mechanics a highly valuable learning experience to both the new mechanic and to TWA.

(Frame 20) An overall review of the results obtained from both the field and overhaul base P-I-T programs reveals that the results of both programs have been significantly beneficial. The key elements of these results are: the proper development of work habits, a contribution to lower mechanic turnover, reduced training cost, and increased mechanic productivity. In addition to the results associated directly with the program itself there are a number of additional advantages that are made possible through the qualities of the instructor group itself. P-I-T instructors are viewed by most mechanics as knowledgeable, and helpful people, and through their capacity to lead, guide and direct, they effectively provide closer technical supervision of all mechanic personnel. These instructors often serve as an additional source of information. In many cases they serve as the humanizing link between the mechanics' need-to-know and the present maintenance information system.

They are also helpful in providing one-time only training and support often required to accomplish aircraft modification orders. These instructors are available for scheduled and non-scheduled classroom training during slack workloads, thereby taking better advantage of otherwise not fully productive time. On occasion P-I-T instructors have served as back-up individuals for extraordinary specialty foremen requirements. We have yet to demonstrate the advantages of P-I-T instructors during the introduction phases of major new aircraft programs, but we believe significant benefits will result in this application.

(Frame 21) TWA's next major new aircraft introduction will be the Boeing 747. Interestingly, the 747 will operate out of both LAX and JFK where the P-I-T program will have been in operation for three years. At these stations we are looking forward to providing P-I-T support for all mechanics during the 747 introduction. Through intensive training we plan to develop in-depth knowledge within the instructor group on the 747. To the extent practicable and possible we hope to reduce conventional non-productive new aircraft classroom training and shift part of our 747 new aircraft training emphasis towards applied learning with appropriate follow-up as required.

(Frame 22) As we look into the future the two things we see clearly are more and more new mechanics and more and more new and different types of aircraft. If we look into the future from the mechanic's viewpoint it is quite clear that he will require additional assistance and support in the way of increased job

information and in the way of development of new and different job skills. One of the most important things we have learned from the P-I-T program is that there is a close relationship between the state of the maintenance information system and the amount of routine (informational transfer type) training that is required to support a given aircraft or power plant. Our experience leads us to conclude that when a mechanic has ready access to the information needed to perform most maintenance tasks he needs relatively little training to work effectively. On the other hand when he does not have the information to perform a given task he requires relatively more training and assistance to perform effectively or he feels his way along at the expense of productivity. When a mechanic is assigned to perform a maintenance task he needs information to answer the following six questions:

1) WHAT am I supposed to do?
2) WHERE or on what does this work have to be accomplished?
3) WHAT RESPONSE will indicate that the job is properly completed?
4) How does this work affect the rest of the aircraft and its SYSTEMS?
5) what is the proper and safe order of the individual work STEPS that are to be accomplished?
6) What tools, parts, supplies, and MATERIEL are necessary to accomplish the work?

We believe that in order to maintain safe and efficient maintenance work that better methods of formatting and presenting maintenance information should be utilized to support the mechanic of the future.

We are hopeful that these changes will come about in the near future and that training in the area of mechanic knowledge requirements will largely be devoted to the required learning to make each mechanic a competent and proficient user of improved maintenance information systems rather than a human reservoir of maintanance task knowledge.

We believe that future maintenance training methods will take full advantage of improvements in advanced maintenance information systems and that the emphasis of maintenance training in the future will more fully emphasize the analysis and development of both basic and critical maintenance job skills required to support future aircraft.

PLANNING, SCHEDULING, and TRAINING

in

UNITED AIR LINES' AIRPLANE OVERHAUL DIVISION

ASSURES THE EFFECTIVE ROLE OF THE

MECHANIC

by

J. R. Stevenson
Airplane Overhaul Manager

It is obvious that the maintenance of a modern commercial jet is a monumental task requiring considerable know-how. It wouldn't do to turn even experienced mechanics loose on such a complex, expensive, potentially lethal machine without special training.

On the other hand, it is entirely too much to expect that all the requisite knowledge and skills be acquired by any single human being. So a natural, logical alternative follows -- team effort, pooling of capabilities, in which various members contribute specific special skills.

This, however, is not the total answer. The know-how must be developed, both quantitatively and qualitatively, and then utilized effectively. This is my topic for today -- how one airline matches mechanic staffing and training to the skill requirements of airframe overhaul for quality workmanship and productive efficiency.

United Air Lines' aircraft maintenance program, like most, includes progressive block airframe overhauls and assorted periodic line checks.

(Slide) The overhaul work is done at the San Francisco Engineering & Maintenance Base. Checks are handled at the various Line Maintenance stations across the system -- per technical information supplied by the Engineering & Maintenance Base.

(Slide) Virtually all serviceable components needed in both Base and Line Maintenance activities are supplied from the Base.

When airframe overhaul is due, United's plan calls for turbine aircraft to be out of service for only six days

(Slide) Five of the days -- 15 consecutive shifts -- are spent in an elaborate overhaul dock.

(Slide) The sixth day is for ramp work and test flying. During the six days, as much as 15,000 manhours can be expended.

(Slide) Let's take a look at the planning of a typical DC-8 overhaul visit. Well in advance of the arrival of a jet for overhaul, a comprehensive maintenance analysis is made.

(Slide) The people doing this are invariably experienced technicians who are well acquainted with maintenance procedures and the skills required of mechanics.

(Slide) A breakdown of 11 skills is used. In the general mechanic categories are cockpit, air conditioning, rigging, fuel, engine, and hydraulic specialities. Besides them are the radio-electric, sheet metal, cabin, paint, and cleaning skills.

(Slide) From historical records, change orders, and various other documents, the predicted workload in each skill category can be compiled for the routine or planned jobs.

(Slide) All of these documents are available to the planners who are analyzing the work to be done.

(Slide) Similarly, although non-routine work cannot be predicted with precision until the airplane is inspected, the amount and type of work resulting from inspection write-ups can be approximated.

(Slide) With this information, manpower profiles for each skill through each day of the overhaul can be plotted. These profiles show the amount of manpower that must be supplied in each skill during each shift.

(Slide) Of course, manpower requirements vary greatly from shift to shift. In general, the overall workload builds rapidly through the first few shifts, then declines moderately through the remainder.

(Slide) You can see that staffing a dock at a constant manpower level would pose many problems: surpluses at some points, deficiencies at others. This led to the Variable Staffing Plan.

(Slide) What variable staffing does is shift some personnel from dock to dock to build up manpower when and where needed. This enables the docks to be staffed for a middle-level workload yet be capable of meeting peak loads efficiently.

(Slide) Since having more than one airplane come in at the same time would compound the peaking and create added staffing problems, simultaneous entries into overhaul are avoided. Typically, a DC-8 or 720 enters overhaul on Sunday night. A 727, on Wednesday night. This distributes the peaks and valleys so that they tend to offset each other.

(Slide) The key to success with Variable Staffing is in matching the mechanic skill qualifications with the workload profiles.

(Slide) Manpower planning analysts start this process by consulting computerized qualification and training records. These show the manpower availability by skill and shift. Added complexities are introduced by the mere fact that the Airplane Overhaul Division is responsible for many aircraft besides those going through overhaul.

(Slide) With a fleet of some 300 jets, many are always being routed to the Base for repair or modification. They compete with the overhaul docks for manpower, and allocations must be made from the same basic pool of skills. In a typical year the Airplane Overhaul Division handles more than 80 jet airframe overhauls plus around 600 airplanes on "special route".

(Slide) With the skill profiles for guidance, Central Manpower Planning makes personnel allocations to the various work centers involved with the overhaul.

(Slide) Later, the mechanics receive specific job assignments.

(Slide) Meanwhile, work planners have been preparing job cards covering the pre-planned routine work and the modification projects. These are set up in the proper sequence in each of 11 skill planning boards at the dock.

(Slide) Release of the job cards also triggers withdrawal of parts from stock or other sources so that they arrive ahead of need.

(Slide) Job cards are detailed sufficiently to enable mechanics to perform the assignments with a very high order of reliability by following the printed sequential steps.

(Slide) As soon as the aircraft to be overhauled is in the dock, it is opened up and units that are scheduled to come off are removed. This is completed within five shifts.

(Slide) Inspection starts immediately, and as write-ups are filed, supervisors and lead mechanics process them, determining what work is to be done, when, and what parts will be needed.

(Slide) Planners then fit in the non-routine work with the pre-planned routine work, integrating the two for efficient accomplishment. This means that, as the overhaul progresses, each job, non-routine as well as routine, must be accomplished in proper sequence and within allowable time and quality limits.

(Slide) Planners and foremen have available a computer run containing mechanics' experience and qualifications history. This is updated continually to enable the dock supervisors to better match the know-how to the type and amount of work to be done.

(Slide) Eighteen on-the-job instructors cover three shifts and work with mechanics in areas of new job accomplishment, review, and qualification. Critical jobs of each skill are carefully identified and are included in the development schedule of each mechanic. Schedules are pre-planned to provide sufficient quantity of personnel that are qualified in the various skills. Qualifying requires actual performance of work within established standards of time.

(Slide) Qualification records must be signed by both the instructor and the supervisor of that skill. Generally, a mechanic is not considered qualified for more than three skills -- the ones he has had the most recent training and experience in.

(Slide) New work of a major nature requires either classroom or on-the-job training, or both, prior to accomplishment on the airplane. Such schooling is provided by the permanent Training Unit that operates as a part of the Airplane Overhaul Division.

(Slide) The Training Unit also keeps and updates the qualification records on all mechanics. When workloads permit, refresher courses are conducted.

(Slide) A high percentage of "standby" time, inherent in the airframe overhaul operation, is devoted to training purposes.

(Slide) Home study and programmed instruction courses such as blueprint reading, basic electricity, hydraulics, etc. are also provided by the company, and this is being expanded regularly. In recent years, the training conducted in the Airplane Overhaul Division has averaged about 80,000 manhours per year.

(Slide) In summary, there are five principal ingredients in United's program to keep mechanics properly trained for the work they're required to do.

(Slide) The first is a carefully developed understanding of the job skills and knowledge needed to overhaul the aircraft.

(Slide) The second is accurate advance knowledge of the work to be performed, so that skill requirements are known.

(Slide) The third is a long-term program which trains mechanics to the analyzed skill requirements by the means most suitable to the training objectives, and with on-the-job training measured for effectiveness by practical performance of the job within standards for quality and time.

(Slide) The fourth is maintenance of accurate and readily accessible training and qualifications information to enable planners and supervisors to assign the right people to the work and to enable adequate advance planning of the training required for both new and recurring work.

(Slide) The fifth is use of job cards which, although serving many purposes, contribute to the training and qualifications of the mechanics and assist in getting assignments done properly and on time.

(Slide) In conclusion, I want to say that we do not see the program I've described to you as the ultimate. It is merely one we have evolved and use today with some success. The process of upgrading capabilities is a continuing one, and we must be sensitive to all factors relating to knowledge, experience, and potential of people.

(Slide) Investigation and development of new and more effective methods are essential if we are to meet the problems of effectively maintaining the jumbo jets and the supersonic aircraft of tomorrow.

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MAN IN THE MAINTENANCE SYSTEM

In opening, I would like to express my thanks to those who have invited my Company, Atlantic Aviation, to participate in this Symposium.

I have been asked to present the thoughts of my employer, a large General Aviation Sales and Service organization, on The Man In The Maintenance System. In doing this, I feel that for the purpose of this subject we can logically assume most repair facilities to have similar problems and possibly the same answers for them.

I am sure that all here today realize that it wouldn't be possible for the schedule to allow all corporations to be personally represented here. Therefore, I hope that our feelings on the subject will prove to be a fair representation of most fixed-base operators.

First of all, I would like to define the group of men who make up the term "Man", in The Man In the Maintenance System. Back at our home base, we have approximately 159 men whose duty it is to inspect, repair and service various types of aircraft of both corporate and private operators. Of this figure, 20 men are in the Avionics Shop, 27 are engaged in the maintenance and repair of aircraft of less than 12,500 lbs. gross weight, 79 are in the Heavy Maintenance Shops and 33 in Line Service. It should be mentioned, that these men are not normally required to do any installation work on interiors or avionics systems. These jobs are considered specialized areas, and therefore, are handled by other people in our organization who are skilled specifically in these areas.

In effect, we can say we have approximately 159 men at our home base of operations who are actively engaged in our aircraft maintenance systems, airframe and powerplant type of work.

The next thing we must define is the word system. According to Webster's Dictionary, a system is "an essemblage of objects united by some form of regular interaction of interdependence." Based on this definition, an aviation maintenance system would consist of men, aircraft, hangars, ground handling equipment, and other special tools, spare parts, and maintenance and parts manuals. I have put the men at the beginning of the list for a particular reason. That is to illustrate that the man might darn well be the most important of all parts of this system, and definitely the hardest of all to come by. That is to say - good, knowledgeable, heads-up type of maintenance people.

Paper presented at the FAA Maintenance Symposium THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM at Oklahoma City, December 3-5, 1968, by Robert J. Greer, Training Supervisor, Atlantic Aviation Corp., Wilmington, Delaware.

If you think back, when you went to purchase a special tool or build a hangar, you were usually pretty sure of what you were getting before you paid for it. You also had some idea of its useful life. Is this the case with our manpower requirements? Of course, we do have our standards, a licensing procedure which sets minimum standards for mechanics, but we must not forget that in this age in which we are living, those tickets can be considered as nothing more than learner's permits. A man fresh out of school with his ratings should be, if nothing else, a good pupil. In order to get him into the system, his training should begin immediately and from that point on, should never stop. We must not forget this.... You cannot stand still in an age such as ours. If we do, everything else will pass us by. Actually, standing still is the same as backing up.

In the past few years, we have been witnessing amazing changes in our chosen profession. Changes which are requiring at least a similar amount of up-dating in us

Our supply of qualified mechanics, has not been able to keep up with the demand. It is becoming more difficult every day to keep our shop staffed with good maintenance personnel. Our sources have been primarily from two areas, the A & P mechanic's schools, and from the Military. I would like to mention that both sources have their advantages and disadvantages.

The average man coming to us from an A & P School, has book knowledge, but generally lacks a matching amount of practical experience. The average Military man has experience, but is not nearly as well rounded in all systems, as is the A & P School trained man.

We have been working with men from both groups with very good results, by tailoring our training to suit the individual. Our real concern for the future is, will there be a larger pool of men from which to draw, two years from now?

Our thoughts seem to be moving in this direction, would it be advantageous for Atlantic Aviation to get involved in a program of training which would start with a new man completely untrained in Aviation, and take him through the basics, into the advanced technology, and possibly working with him until he obtains his Airframe and Powerplant licenses?

Along with our need for mechanics to expand, we have the usual attrition problem which faces most companies. We have through the years lost good men to various corporate operators and airlines. To stem the tide of this loss we are doing our utmost to remain competitive in areas of salary and benefits. Other losses of good experienced men from the floor to jobs of greater responsibility in the company, cannot really be stopped, for this makes for a sounder management, but we must be prepared to replace these men.

If we are to continue to prosper in General Aviation, we must advance with it. We must take our mechanics, both the new ones as they come through the door on the first day, and the old hands as well, and we must continually remold them. Things are changing so rapidly that the mechanic of 10 years ago would be utterly lost in our shop of today.

We have been witnessing phenominal growth in our aircraft of greater than 12,500 lbs., in the past few years, and we can not foresee a leveling off of this in the near future. However, in the next five years, we will be part of an even greater rate of growth in our lighter aircraft, Who here cannot see the start of a trend toward turbo-prop and pure jet aircraft, from manufacturers such as Beech, Cessna and Piper? Isn't the handwriting on the wall? We will see fantastic inroads into light aviation by the same engineering which we are starting to live with in the heavy aircraft.

Naturally, when we put a turbine of any sort on an aircraft, we must fly higher for engine efficiency. This, of course, will require air conditioning and pressurization systems to be aboard even lighter aircraft than now have them. Along with this goes more advanced instrumentation than we are now used to in this type of aircraft. In other words, we are going to see all our problems crop up time and again, and as a matter of fact, for each different plane, we will have problems to overcome. For no two manufacturers have the same answers for a given problem.

Sometimes I think back to things I have read about the Wright Brothers who pioneered our industry 65 years ago. Can you imagine their thoughts if they could get a look at one of the more sophisticated corporate jets, such as the Grumman Gulfstream II. I can just about see Wilbur turning to Orville and saying "Wilbur, I'd sure like to get a look at the bicycle shop where they put that flying machine together."

Isn't it amazing the lengths that we have gone to for air travel? Naturally, all these things are necessary in order to keep air travel safe, while greatly increasing the speed, range and comfort of flying.

All of the advancements in technology which have been brought about through the years, amount to the logical progression of systems and servo-mechanisms; but when all of these advancements are brought together in a single unit such as an aircraft, it becomes a formidable task for maintenance personnel to get a thorough workable understanding of each of them.

It takes a good mechanic with a particularly receptive mind to gain insight into the complicated systems which we have been phased into for the past few years.

With the progress which has been made in the last 10 years, one can hardly help but wonder what lies ahead in the 70's. I see the future as one of the greatest challenges the fixed-base operator has to handle. A challenge which will have to be met. One in which we are going to be hard-pressed just to keep up, with the changes in aviation.

Based on this challenge, I believe that all of us in aviation are duty bound to motivate our personnel in such a way, that they will want to keep up with the advancements in electrical and fundamental electronics, as well as, the changes in flight controls, instrumentation, powerplants, and other systems.

All operators are slowly being forced to make decisions concerning whether we intend to have our electrical technicians trouble-shoot airframe system problems, which have been up until now in the realm of the airframe and powerplant mechanics. This change in attitude toward troubleshooting would require a larger force of electrical specialists. On the other hand might it not be more useful to train the mechanics to a higher level of electrical and basic electronics knowledge? For these are the men who have the most experience with the workings of the systems in question. As an example of an aircraft of the 70's, let us consider the Gulfstream II aircraft which we have been living with for 1-1/2 years now. As I think back on the systems of this aircraft, I can remember only one system which does not require electrical power in one form or other. That is the door-seal inflation system. By comparison, we cannot even trust our old standby the hydraulic pump anymore, as this aircraft even has electrical connections on this old mechanical workhorse. The point I am trying to make here is that the advancement of technology, in the effort to make things more reliable, has actually made things more complicated for the man in the maintenance system.

The mechanics are finding themselves responsible for the proper use and interpretations of results from such units as; air data testers for pitot/static systems, anti-skid system testers, variable inlet guide vane testers and other special test equipment too numerous to mention. How many of us can remember things of this nature from 20 or even as few as 10 years ago?

As a friend of mine once said to me, after I had just rapped my head against a drain valve on an engine, "Bob, we are just going to have to learn to be smarter than the equipment we work on." Right at that moment I didn't take the time to think about what he had said in jest, but these words are proving true. We are being forced by progress to become as sophisticated as the equipment we work on.

You know, this isn't really going to be easy for most of us, because some of the units which could fall into the jurisdiction of an airframe and powerplant mechanic, for troubleshooting purposes, are well beyond our capability, to be thorougnly understood. One such unit as an example is an Electronic Start and Overspeed Control Box, which is a part of a Gas Turbine Compressor, fitted as an Auxiliary Power Unit in one of our aircraft. This unit contains no less than 40 transistors and 30 diodes. Yet its sole purpose is to turn the fuel and ignition on and off at the proper time, drop out the starter, and give an indication of turbine speed in the flight station. I believe we all would have to agree that the starting and proper running of this unit is a Powerplant mechanic's job, yet we are expecting him to have a bit more than a cursory knowledge of electricity. I do not want to infer here that our mechanics are expected to troubleshoot the inside of this box, but by mere association with it, we must have some knowledge of its inner workings. Just to give an illustration of the importance of this unit, if it does not function properly the APU will not run. If the APU won't run the main powerplants won't start, as they are fitted with pneumatic starters. As you can see, this could bring unusual pressures to bear on the mechanic for not only accurate troubleshooting, but also rather rapid troubleshooting. I would imagine that few things would look more useless to a busy executive than a $3,000,000 airplane that can't get its engine started.

There are no less than 18 other units which could come under an aircraft mechanic's job description, that is if he is to thoroughly fulfill his duties. All of these units are transistorized, in keeping with our updated technology. Eighteen (18) units is a conservative figure and does not include any autopilot, radio, or navigation equipment. So you can see this trend is bound to continue rather than diminish.

In trying to keep up with this advancing technology, we turn primarily to the factory schools for the knowledge of the systems in their aircraft. This, of course, is the only logical place to gain this advanced information. However, we being in business to show a profit find it very difficult to justify the expense of factory training for all of the men in our employ. Actually, to be honest, not all the men would get full benefit from factory training, as not all of the men are at the skill level needed to absorb the majority of the information which would be presented. As an example, of our group of [illegible] maintenance people in our Heavy Maintenance Group, we have in the last 18 months accounted for well over 2,000 man hours of factory service schools. This time was well spent because it represents approximately one (1) out of every five (5) men in the organization having attended factory training. The difficulty with this type of training is that four (4) out of five (5) will not share in it. To neglect this large group of men would be a mistake, especially with the advances in technology we have seen in recent years.

In an effort to update this large group of men Atlantic Aviation has set up a full time in-house training program. This program, in the last 18 months, has accounted for over [illegible],000 man hours of training. We feel that this program is one method of evening up the training unbalance which had existed in recent years. In this way, we have been able to augment our usual on-the-job training program. We feel it is our duty to our mechanics and the company and to aviation to have our maintenance personnel brought along through these difficult years which are to follow.

As an indicator of our success with the in-house training program, it has been expanded to include a second full-time maintenance instructor whose primary area of interest lies with our light maintenance group. At present, we are pursuing a course of training which will have all of our light maintenance group trained in the Beechcraft [illegible] by the end of the year. This particular course is of a 64 man-hour duration for each student. In passing, I would like to mention that by the end of this year, our entire force of men in the Heavy Maintenance Group will each have a minimum of 160 man hours of training on the Grumman Gulfstream II systems.

A second indicator of the success of our training comes from the men themselves. Though subtle, a change in the attitude of the man is taking place. There is a definite improvement in the team spirit. I believe the men have a greater appreciation of the company and their place in it, by the investment the company has made in them. As a matter of fact, of the 30 unlicensed mechanics we have hired in recent years, over 1/2 have obtained their Airframe and Powerplant Ratings. Here agin, the company helps to motivate the men along this line by allowing time off for testing, among other things.

In closing, I hope that I have conveyed to you the thoughts of our company concerning the mechanic in the maintenance system of today as well as tomorrow. We are looking forward as a team to the coming of the 70's, hoping that through training and good employee relations we can continue to remain in step with the advances which are headed our way.

We will see some new aids among the tools of the mechanic of the future, not the least of which will be the computerized maintenance system. These systems will help us keep track of all the work which must be done on these flying machines. Let us not forget though, they can only aid our maintenance people and not replace them.

At Atlantic Aviation the men are our maintenance system. All we have done is backed them up with a full range of training according to their needs and put at their disposal several million dollars worth of tools, facilities and other aids.

Thank you...

THE NEW ROLE OF THE MAN IN AUTOMATED TESTING

Laurence S. O'Neill
United Air Lines
San Francisco International Airport, California 94128

INTRODUCTION

Rapidly increasing maintenance costs and shortage of skilled manpower have led several airlines to implement Automatic Test Equipment (ATE) in the shop testing of avionics units. Automatic testing offers sizeable reductions in test time which, for various reasons, is extremely attractive to airline operators. ATE is no panacea of course, and its successful implementation faces a number of interrelated man and machine problems. The sketch on the following page illustrates one aspect of the problem; the man in maintenance and his misconceived fear that his present skills will no longer be required. This discussion, in question and answer format, is a look at ATE from the standpoint of the people who are responsible for integrating it into airline maintenance.

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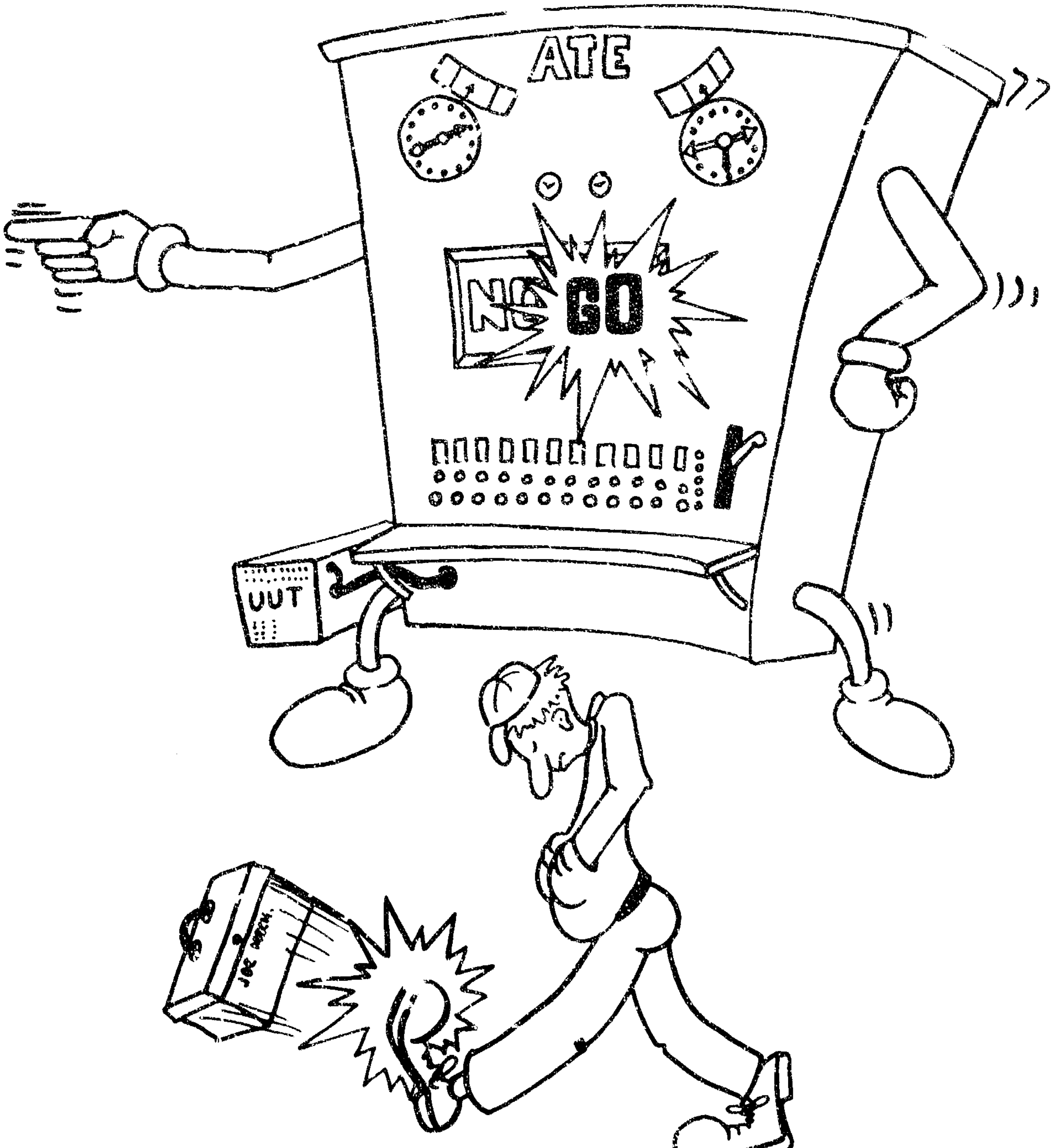


THE MAN IN AIRLINE MAINTENANCE AND HIS MISCONCEIVED FEAR THAT ATE WILL REPLACE HIM

BAC. ̄RC ̄D

United Air Lines has placed an order with Collins Radio Company, Cedar Rapids, I for an initial complement of ATE for use at the San Frar ̣sco avionics overhaul facility. The equipment is scheduled for delivery in November, 1969 and will consist of two major elements; a test station for electronic flight control equipment and a digital computer to control and monitor the test station :cording to preprogrammed test procedures. We plan to add appro ̄imately one test station per year to the computer to test other functional groupings of avionics such as radio frequency, air data, and digital systems. Applications outside of the avionics area are also being considered. Current active investigations include such diverse but promising applications as fuel control system, turbine engine, and electrical access testing. The decision to implement ATE on such an extensive scale wa based on our prior experience with special purpose, semi-automatic test systems. We also relied on information provided by airlines and manufacturers who have been using general purpose ATE for some time.

PRESENT UAL SYSTEM

Before discussing the new roles of people with ATE, we should take a look at the present individual responsibilities for avionics testing. The key characters in the scheme are the engineer, test equipment designer, procedure writer, and production mechanic. The descriptions which follow are not inflexible; and in many cases, all or part of the test development is conducted concurrently or assumed by an individual other than the one with the formal responsibility.

ENGINEER

The system engineer's formal responsibility with respect to avionics maintenance is to furnish the maintenance organization with the minimum test requirements each unit must pass to be returned to service. The depth of detail and medium of communicating these requirements varies from unit to unit depending primarily on its complexity. The engineer bases his specification primarily on his own experience along with Customer Test Specifications, Service Bulletins, and other formal or informal communications

which are provided by manufacturers, FAA, or other airlines. He performs continual follow-up to assure that the test is properly implemented and reflects the latest available modification information.

TEST EQUIPMENT DESIGNER

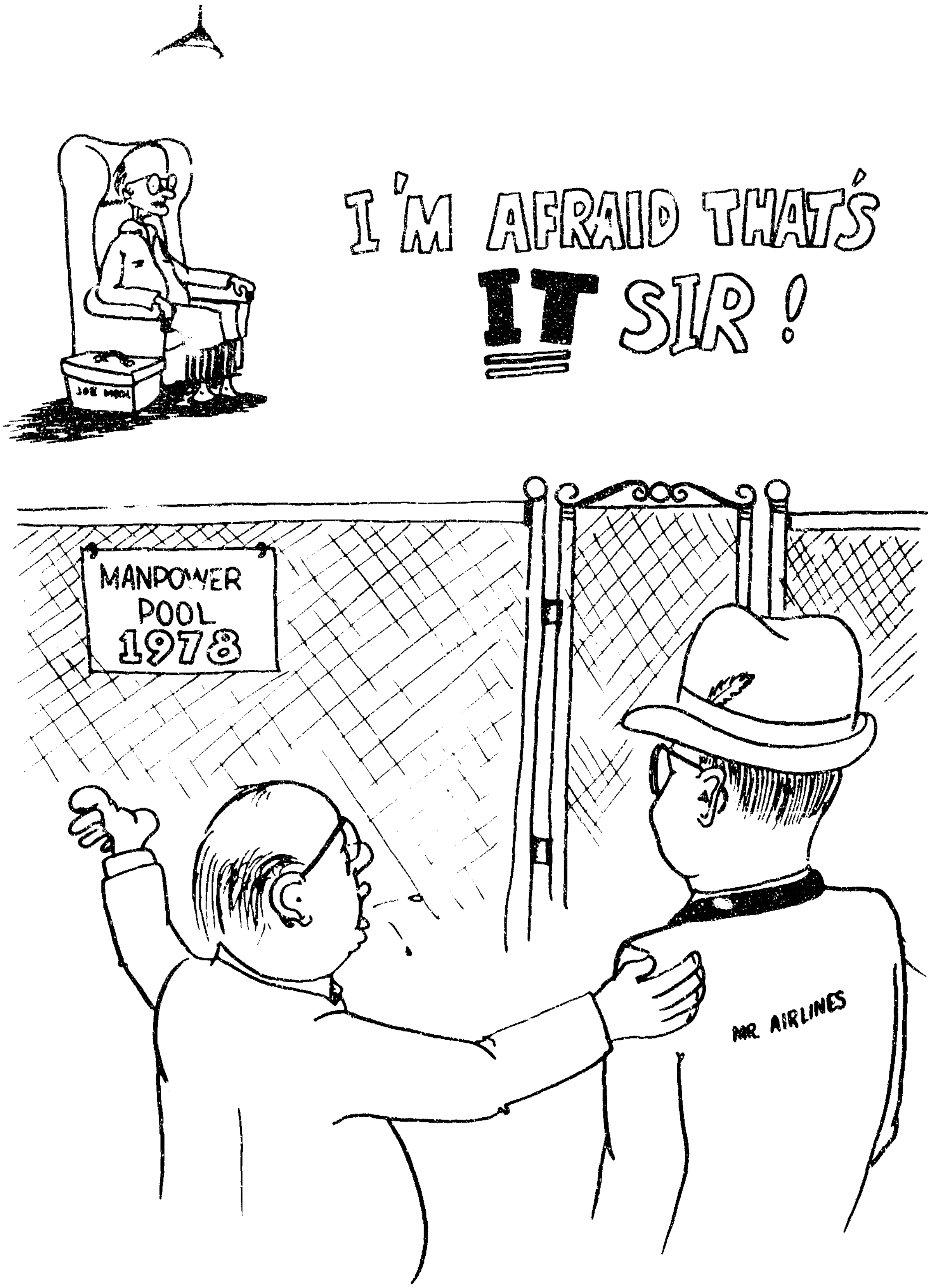
The engineering test requirement is communicated to the technical staff of the maintenance organization. The test equipment designer is usually the first to review it to determine the requirements for test hardware. He follows normal design practice in making the build or buy decision for the required test equipment. In the majority of cases, however, UAL will build the special purpose test stand for the unit; and the test equipment designer proceeds to design and co-ordinate the manufacture of the equipment.

TEST PROCEDURE WRITER

In another area of the technical staff, a procedure writer integrates the engineering test requirements and the test equipment design along with mechanic's advice on optimum methods to produce the written instructions to the person who performs the test. Again, the amount of adaptation required at this stage depends on the level of detail of the particular engineering test requirement. In most cases, the "procedure writer" tag is a gross understatement because his work involves extensive liaison with the engineer, test equipment designer, mechanic, and many others to obtain a workable, efficient, and meaningful test routine. A large part of the task is in the initial certification and de-bugging of the test before it is released for production use.

PRODUCTION MECHANIC

As the executor of all the technical planning, the production mechanic is the most indispensible link in the maintenance chain. His duties are not limited to literal execution of the written overhaul procedure. On the contrary, the most productive aspects of his work, fault isolation and repair, are only partly described in overhaul manuals. He supplies the rest from his training and experience and the application of good general maintenance practices. The mechanic is also the primary source of information on the performance and condition of avionics in service. Without continuing feedback from the mechanic,



WITH PRESENT METHODS AND GROWING WORK LOAD, THE SUPPLY OF SKILLED MECHANICS WILL NOT SATISFY FUTURE AIRLINE REQUIREMENTS

the engineers and technical planners would have no basis for effecting needed improvements in the systems.

MAN AND ATE

Now let's look at the new role of the man in automatic testing. Since ATE represents a significant change in maintenance concept, it is certain to have an effect on individual responsibilities. An impending change characteristically gives rise to uneasiness among those involved, so we have initiated a continuing program of group briefings to eliminate the misconceptions which could deter the efficient transition to ATE. The remainder of this discussion treats some of the questions raised at these sessions and the answers which reflect our best estimate of the impact of ATE in avionics maintenance.

Q. MECHANIC: *You tell me you're buying this ATE for manpower savings. I have less than one year seniority. Does this mean I may be laid off?*

A. It is true that we justified the ATE investment primarily on expected manpower savings, but no one will lose his job on account of ATE. This apparent contradiction is brought about by the fact that with our rapidly increasing aircraft inventory, manpower requirements are increasing much faster than skilled mechanics can be found to fill the new positions. For example, 50 mechanics are presently employed in the electronic flight controls area of the shop where ATE will first be implemented. Using present manual methods, we had forecast a manning level of 200 for this area by 1978. With a gradual transition to ATE during the same period, the 1978 level can be held to slightly more than 100. We recall someone once saying that if the telephone industry had continued to use the manual methods of 20 years ago, they would now have to employ every working age female in the United States to provide their present services. We are fortunate to be part of such a healthy growing industry; but we would soon become a stagnant thing of the past if we failed to take advantage of new technology and more efficient methods.

Q. *MECHANIC: Well, if you're not going to let me go, what will there be for me to do around here?*

A. At present, the mechanic spends more than half his productive time running lengthy, monotonous tests on units in which no fault is found. These serviceable units get into the maintenance pipeline because operational time constraints on in-service aircraft require that equipment substitution be used to correct faulty aircraft systems. Once a unit is removed, whether or not it was the real culprit, it cannot be returned to serviceable stores without first going through the maintenance process.

As have other airlines, we will use the ATE as a filter in the maintenance pipeline to assure that only faulty units reach the repair bench with good units returning directly to stores. For the production mechanic, this will lead to many obvious improvements. Most important, he will be relieved of much of the monotony of his work and can devote his time to fault isolation and repair. This is the true application of the mechanic's skill; and with more time budgeted to this phase, both the quality and quantity of his productive output will increase.

Q. *MECHANIC: When I get a unit from the ATE, I'll probably have to run the whole manual test anyway because I won't be able to read the ATE program to find out what tests it performed.*

A. Here's an area where co-operative planning in the airline industry has paid off. Under the sponsorship of Aeronautical Radio, Inc. and the Airline Electronic Engineering Committee, an airline standard test procedure language has been developed. It is called Abbreviated Test Language for Avionics Systems (ATLAS), and was designed to satisfy the airlines' unique communications needs, especially in the area of ATE programming. The ATE we have ordered includes the capability to automatically translate ATLAS test procedures into the binary machine codes which operate the ATE.

One of the most important goals in the development of ATLAS was to create a language which can be understood by anyone involved in avionics testing with a minimum of training. Since our ATE programs will be written in ATLAS, anyone interested can read the program to find out what tests the ATE performs on the unit. The ATE is also equipped with a hard copy output via teletype which can be

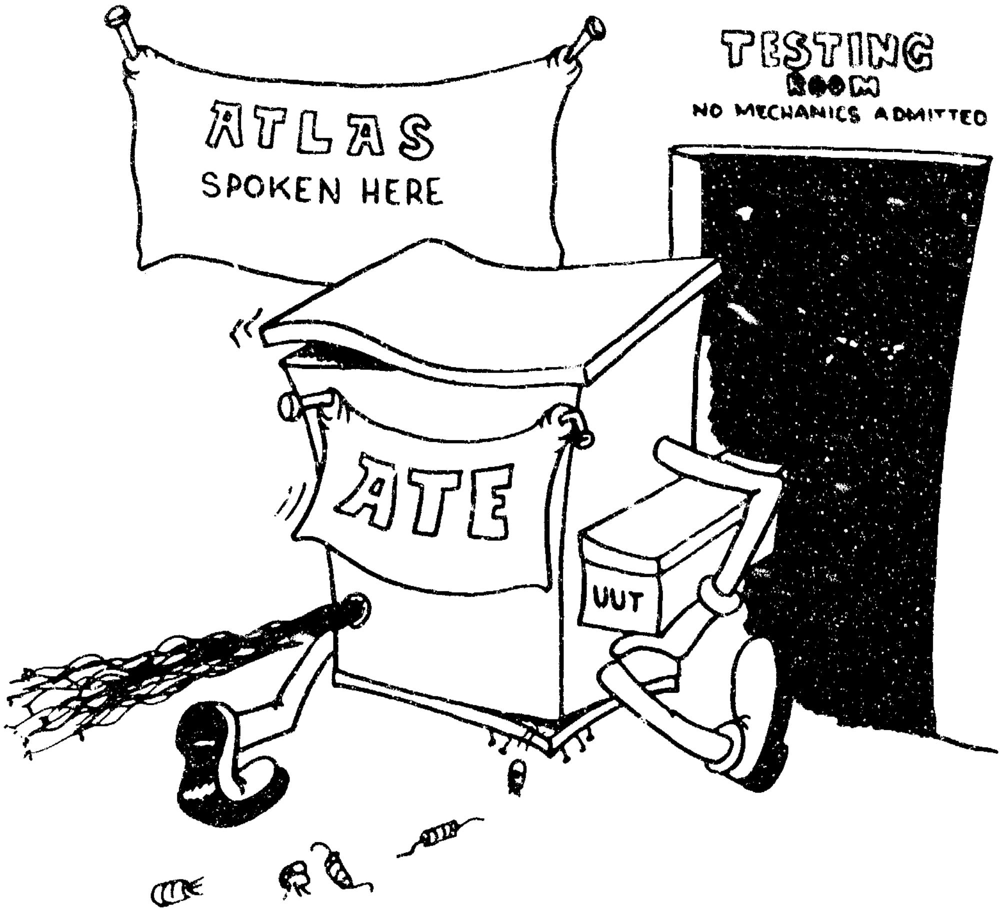
programmed to print clear English messages with any information discovered during the ATE run. The test station operator will pass this printout to the mechanic who can interpret the ATE indications and limit his fault isolation to the most suspect portions of the unit.

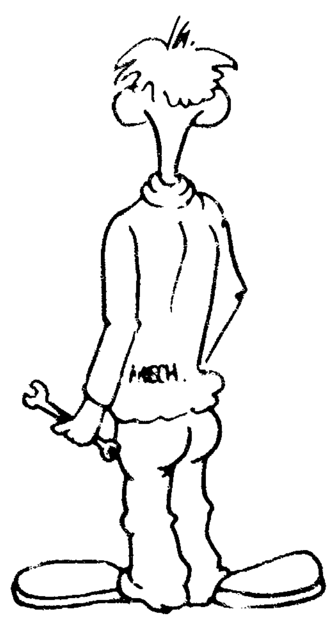
To summarize, our ATE procedures will not be written in any mysterious computer language. ATLAS is employed so that everyone can understand and rely upon the ATE test.

Q. *ENGINEER:* *In the past I continually reviewed procedures and occasionally observed the mechanic's technique for compliance with my test requirement. Now that you're planning to use computer programs instead of written procedures, won't I have to become a programming expert to make the same assurance?*

A. The readability of ATLAS test programs will allow the engineer to review them as in the past, but ATE will do more for the engineer than simply maintain the status quo. With ATE, the engineer has the additional assurance that the test procedure will be executed exactly as written for every test. Thus, by verifying the ATE test one time, the engineer will have a 100% assurance that every unit is properly tested. Of course, the benefits of this feature extend to general management and quality assurance considerations.

The engineer's effectiveness will be improved in many other respects. The ATE will retain historical test results on magnetic tape in a form compatible with most data processing systems. In the past, test results were only available in notations on check lists and unit history sheets which were too voluminous to permit economical evaluation. With machine retrieval of the data made possible by ATE, the engineer can economically analyze unit performance and failure trend data which will often suggest substantial improvements to the unit through modification of the test procedure or the unit itself.





THE MYSTERY OF
ATE PROGRAMS IS
SOLVED BY ATLAS

Q. *TEST EQUIPMENT DESIGNER: Since we don't have to build a manual test stand for each new unit and since I don't know anything about computers, what will be left for me to do?*

A. Although the ATE doesn't change for each new unit, the same design work which formerly produced a unique test stand must now be included in the ATE program. This means that the skills of both the test equipment designer and the procedure writer must be merged to produce the ATE program; and eventually the two functions will probably be indistinguishable.

There remain, however, many requirements for ground equipment design. Although much simpler than a complete test panel, an ATE to unit adapter must be produced for each ATE program. It will consist of the interwiring and special loads and fixtures to mate the unit to the ATE and provide special-purpose testing functions not available in the ATE. For example, one portion of the test of an SP-50 autopilot component requires that the unit be physically tilted and rotated at a constant known rate while some electrical tests are performed. Since this is a one-time requirement, a motor driven turntable must be included in the ATE to unit adapter.

Q. *MECHANIC: There are a lot of things involved in testing my unit that aren't written in the test procedure because I've developed these techniques through practice. If you implement the old manual procedure directly, you'll be sending units out that pass the ATE but would fail the manual test.*

A. It's entirely true that a literal implementation of existing test procedure on an ATE will not result in an adequate test. The manual procedure for a new unit is gradually and subtly refined as the mechanic gains experience with the unit and the procedure, and it is often difficult or impractical to incorporate these modifications into the written procedure. It will be most imperative that these subtleties are included in the ATE procedure because the ATE of course cannot learn from experience. Thus, the mechanic must participate much more than in the past in the preparation of test procedures. Here again, ATLAS provides a communication tool which will meet the increased demands for interchange of information. Without the benefit of the mechanic's inputs, ATE testing would be ineffective.

WITHOUT THE BENEFIT OF THE MECHANIC'S EXPERIENCE, THE ATE COULD NOT BE EFFECTIVELY PROGRAMMED

Q. PROCEDURE WRITER: *Wherever I check out a vendor's procedure and test panel, I have to "reverse engineer" to find out what's really happening to the unit under test. Won't that get worse now that the procedure is in computer language and the test panel is now a complex computer?*

A. Again, ATLAS will provide marked improvements in our manner of communicating test requirements. Procedures written in the language are independent of any reference to particular test equipment. For example an instruction in an existing procedure refers to the manual test panel. Example: "T [illegible] 1 to position 27. Meter M1 should read between 51% and 55%". The same test in ATLAS refers to the unit under test. Example: "APPLY, DC SIGNAL, VOLTAGE 28V, CNX HI J1 - 51 LO J1 - 52$ VERIFY, (CURRENT), AC SIGNAL, UL 1.5MA LL 1.0MA CNX HI J1 - 13 LO J1 - 14$" In the ATLAS version, it is clear that when 28 vdc is applied to pins J1-51 and 52, 1.0 to 1.5 milliamps of current should be measured at pins 13 and 14. With this consistent unit under test orientation, the real test requirement will be immediately evident without reverse-engineering the special-purpose test panel.

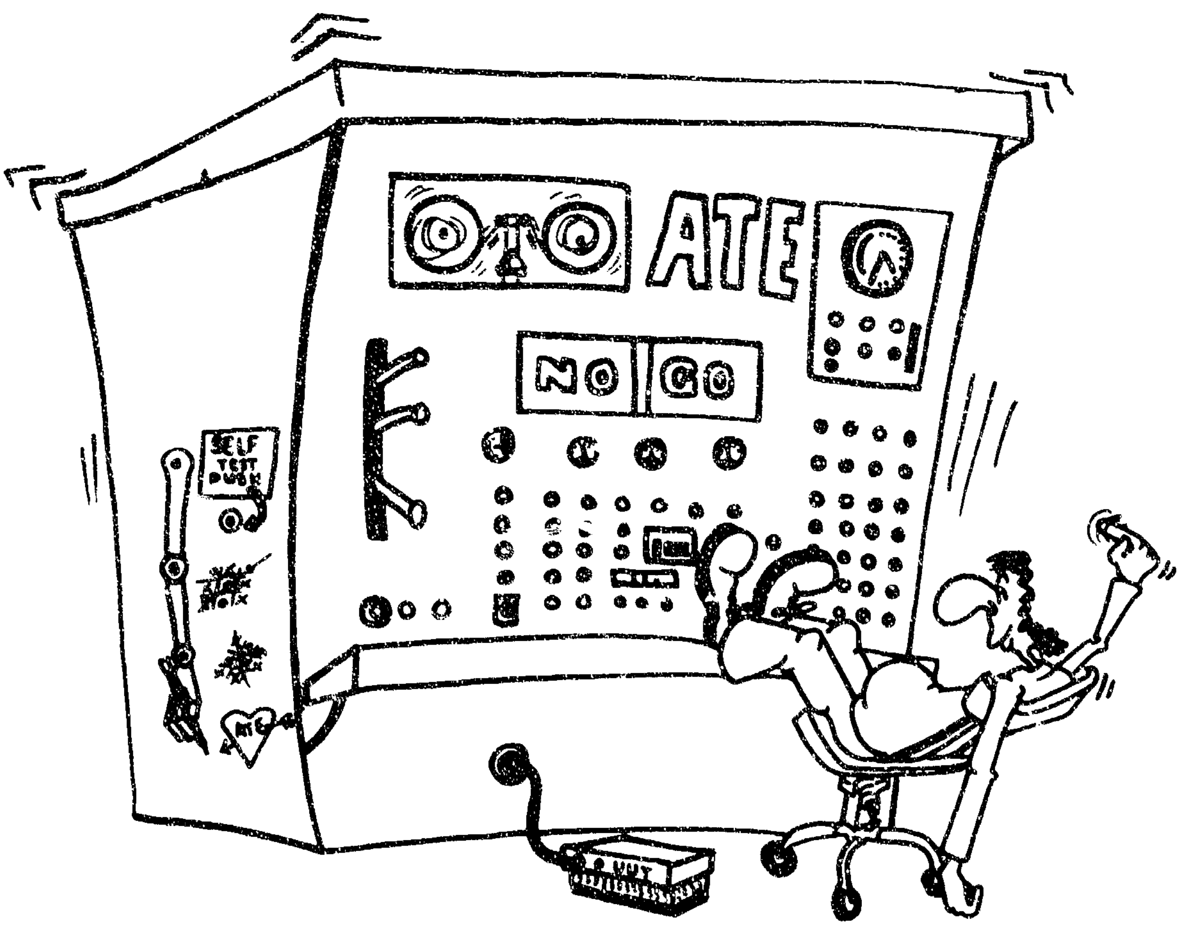
Q. PROCEDURE WRITER: *Will you be hiring a bunch of computer programmers from outside to take over my assignment?*

A. The answer is definitely no. It has been conclusively demonstrated in every testing application we know of that knowledge of the tested unit is the key to successful ATE programming. If we had to process our test instructions through a programming element which had no knowledge of the application, much of the meaning of the test could be lost. We have therefore invested heavily in computer capacity and compiler programs to enable us to automatically translate ATLAS procedures for direct execution on the ATE. Using this high level language the engineer, procedure writer, and mechanic can assure that their intentions are reflected in the test program. We will, however, have some capability to program the computer directly in machine codes for purposes of maintaining the computer executive programs and computer hardware itself; but this will be minor in comparison with actual test programming.

THE ATE PROGRAMMER MUST BE SOMEONE EXPERIENCED IN AIRLINE AVIONICS MAINTENANCE - NOT A THEORETICAL PROGRAMMER WITH ONLY COMPUTER FAMILIARITY

Q. *AUTOPILOT MECHANIC: Although some phases of my job are pretty boring, it requires education, experience, and unique skill. Will I be reduced to a button-pusher when this ATE is implemented?*

A. We have already pointed out that the new role of the production mechanic will demand greater knowledge and ability, but this question correctly recognizes that the ATE will be creating some new personnel assignments. One typical position is the operator of the test station itself once the ATE is programmed. Although we expect his duties to be less creative than the mechanic's, he should not be characterized as a button-pusher. He will supply via keyboard all the human inputs required by the test program such as unit serial number, date, and indications such as lights and meters which the ATE cannot evaluate. He will also report the ATE indications for failed units to the mechanic who will perform the isolation and repair. This may sound routine to many mechanics, but we must recognize that there are people who are ideally suited to this type of assignment.



OUR BRAINS WON'T EVENTUALLY DECAY FROM LACK OF EXERCISE, WILL THEY?

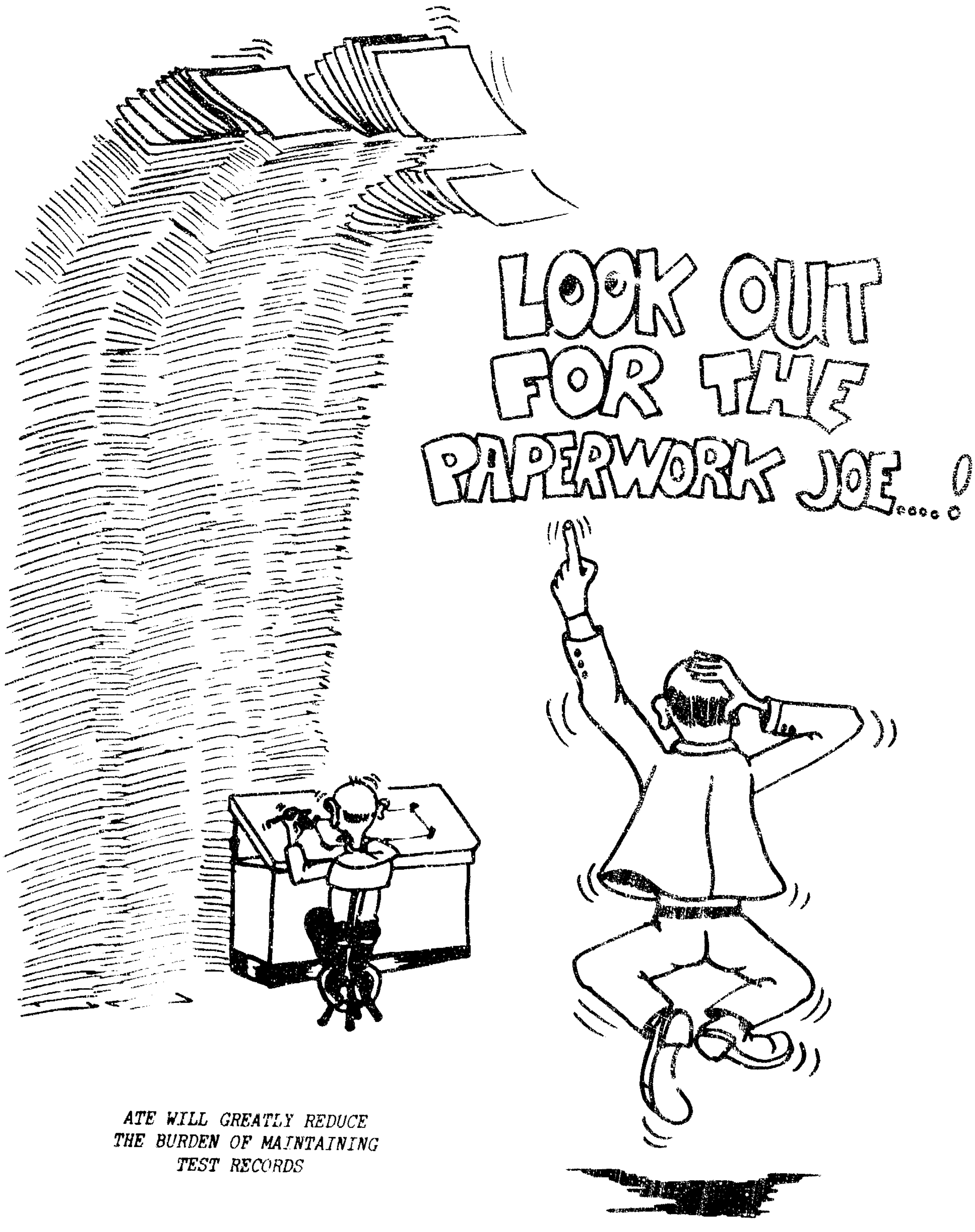
Q. PROCEDURE WRITER: Are there any outside training courses in programming or computers that I should be taking to get in on this ATE business?

A. Additional education is always desirable of course; but for most people involved in this project, previous computer training will not be a prerequisite. Most of the outside courses available are oriented toward general data processing applications and programming languages. As we have pointed out, ours is a special application with a unique programming language and unique hardware in which the computer plays a minor role. The ATE vendor and our own training department will be conducting the required specialized training.

Again, this is not intended to discourage anyone from taking every opportunity to improve their general education and keep abreast of the latest technological developments related to the job.

Q. MECHANIC: This avionics overhaul business is too much of a papermill already. Why add more with all these high speed printers, programs, and tapes?

A. We will be processing more data with ATE than in the past, but the burden on people will be greatly reduced. At present, the mechanic spends considerable time writing test results on check sheets, filling in unit history cards, and maintaining other required records. We hope to maintain most of these records with the ATE using its various output devices. We already discussed how magnetic tape will be used for historical test results that were formerly written by the mechanic. More active records can be automatically output on the ATE printer. Paper messages will be used primarily for the test summary. For failed units, the summary will go to the repair mechanic for his information; and for passed units, it can be attached to the repair tag as evidence of a successful test. For temporary information such as instructions to the ATE operator, a CRT display device will be used. This over-all simplification of the record keeping process will be a welcome improvement in our operations.



ATE WILL GREATLY REDUCE THE BURDEN OF MAINTAINING TEST RECORDS

CONCLUSION

Avionics mechanics, engineers, and technicians in the past have demonstrated their ability to adapt to the rapidly changing electronics industry. Transistors, printed circuits, and integrated circuits were absorbed in stride into airline maintenance with much less difficulty than had been anticipated. The transition to ATE should be as manageable as the previous changes, providing that responsible people take adequate steps to prepare for it. In preparing for ATE, management should not ignore personnel considerations such as those discussed in this paper. Contrary to some popular misconceptions, ATE tends to humanize rather than de-humanize the maintenance process.

ACKNOWLEDGMENTS

The author wishes to express appreciation to all those . United Air Lines who contributed their ideas to this paper. Special thanks are extended to Mr. Robert E. James of the Instrument Group for the illustrations and Mr. W. C. Lehman, Mr. T. A. Ellison, and Mr. J. J. Tordoff for their constructive reviews of the material.

REFERENCE

ARINC Project Paper 416 (Draft No. 7) "Abbreviated Test Language for Avionics Systems (ATLAS)". Copies of this paper may be obtained on request from Aeronautical Radio, Inc. (AEEC), 2551 Riva Road, Annapolis, Maryland 21401.

DEVELOPING THE MAINTENANCE MANAGER

GENERAL INTRODUCTION

INTRODUCTION

Maintenance costs currently run about 25 percent of the total operating costs on the average airline and corporate jet aircraft. In recent years, particularly since the introduction of the jets, maintenance costs have been continuously increasing for both the corporate and the airline operator until they are reaching the point where both are becoming alarmed.

There are three basic reasons for these increases:

> First, the maintenance activity area, while everyone recognizes its importance, has still received relatively little formal attention from management.
>
> Second, the increasing complexity of the aircraft itself, its avionics and instrumentation, and its related equipment. This increase in complexity is reflected both in higher costs associated with parts and with the higher labor rates as greater and greater expertise is being required.
>
> Third, progressive, well qualified maintenance managers who are capable of controlling costs but not at the sacrafice of quality are difficult to attract and retain because they are in such short supply.

As the technology of the total aircraft system increases, the need for better maintenance managers also increases. The major

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Presented at the FAA Maintenance Symposium, THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM, at Oklahoma City, December 3-5, 1968, by Harley D. Kysor, of Harley D. Kysor & Associates, Inc., Management Consultants Specializing in Aviation.

problem seems to be that the aircraft system technology is increasing faster than is the availability of better maintenance managers. The lack of these managers is costly for the operator--whether he performs his own maintenance or "farms it out". As a matter of fact, it is probably more costly when he "farms it out" than when he does it himself, because by doing the maintenance himself, he has some control over the work. By farming it out, he may be placing himself at the mercy of the contracting agency over which he probably has no control--particularly if it is an agency that he must patronize due to franchise arrangements, dealer organization or his geographical location.

THE NEED FOR MAINTENANCE MANAGERS

There have been significant improvements in maintenance techniques and equipment and even aircraft design over the past few years as a result of the efforts of maintenance personnel. However, the future will require even greater improvements in order to improve or even maintain the current level of safety and operational reliability of equipment yet control costs. The use and adaptation of modern management philosophy, principles and methods to the maintenance activity can provide a major assist in helping to meet these objectives. One of the most significant of these management methods which can accomplish a great deal to bring about these improvements is the planned, systematic development of the maintenance manager.

Most men with the title of "maintenance manager" are not managers. They are usually excellent technicians who have been given varying amounts of managerial responsibility--usually without proper management training.

Some have, through trial and error, developed managerial capabilities on their own. This method is, however, in the long run the most expensive and least complete.

The managerial skills of most maintenance managers need considerable attention. This is not surprising as managers are developed--not born. It is prudent for management to recognize this and realize that the duties and responsibilities of the maintenance foreman are considerably different than those of a mechanic. The only way the foreman is going to learn to act as a manager is the same way he learned to be a mechanic--his superior must take an active role in developing his managerial capabilities.

It is the purpose of this study to provide a basic method of and framework for DEVELOPING THE MAINTENANCE MANAGER.

DEVELOPING THE MAINTENANCE MANAGER

CHAPTER I - BASIC CONCEPTS OF MAINTENANCE MANAGEMENT

INTRODUCTION

There is one basic concept of management that will be applied by both the first-line maintenance foreman and the chief executive officer in their respective jobs, i.e. getting things done through other people. The only difference will be in degree.

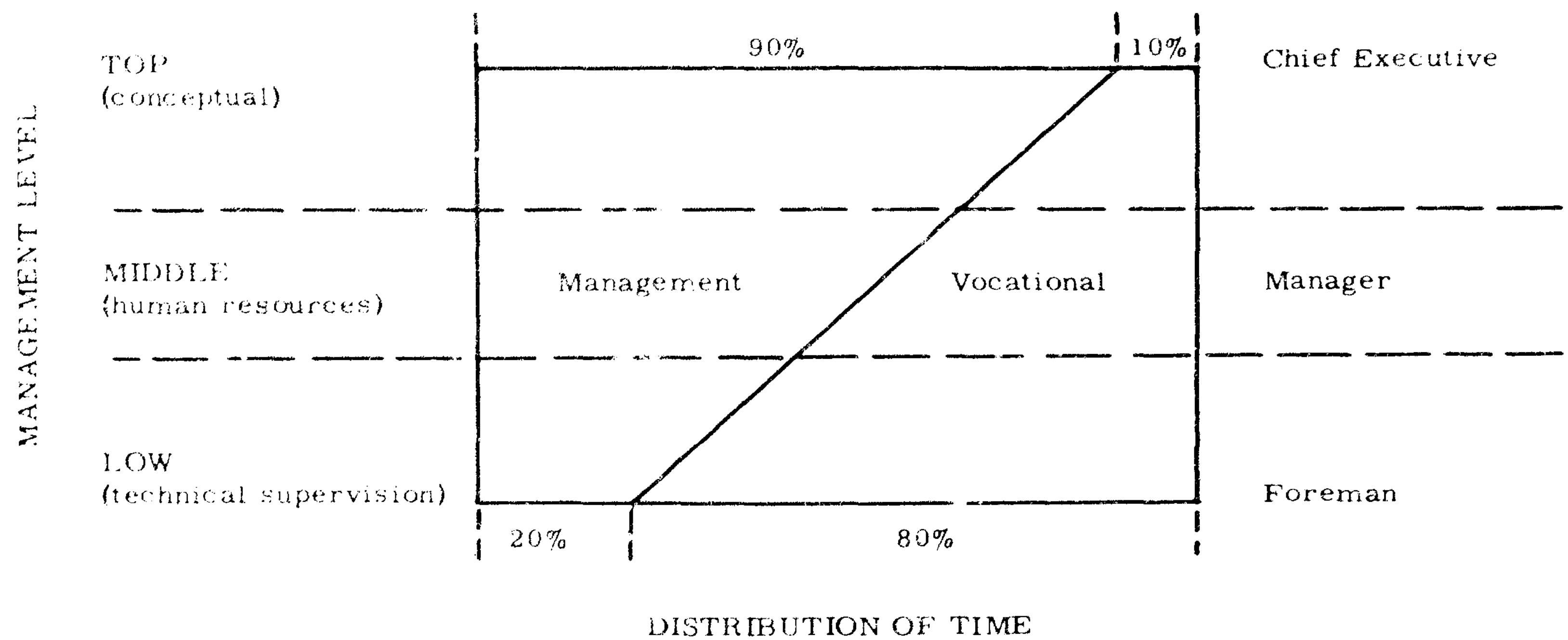
THE TASK OF MANAGING

In our opinion, managing is a profession. It is, however, very different from many functional and technical activities that people may relate to managing. Managing is the work that any individual does when he seeks to get results through other people. As previously indicated, managing can be done at any organizational level from the foreman to the chief executive officer.

DECISION MAKING

Please refer to Exhibit No. 1 - Management and Vocational Decision-Making. This rectangular diagram represents an aircraft maintenance organization. It could be a corporation which specializes in performing maintenance or the maintenance activity area within an air transportation system such as airline, fixed-base operator, or corporate aircraft operator. For the purposes of this paper, we are examining the method of developing the maintenance

Exhibit No. 1 - Management and Vocational Decision-Making



manager or the corporation which specializes in performing maintenance. The reason for this selection is because this organization provides the greatest insight since it has the most complete and complex maintenance structure. Lessons learned here can be adapted to any other maintenance activity.

As we move up in the diagram shown in Exhibit No. 1, we are moving through management levels. In the case of the maintenance organization, we move from the first line supervisor (the foreman) at the bottom of the diagram, to the top management level (the chief executive officer).

The horizontal distance enclosed by the left-hand and right-hand boundaries represent 100 percent of an individual's time on the job--whether it is eight or 18 hours a day.

To illustrate the division of vocational and managerial activities and the distribution of time spent at each activity at the various management levels, a diagonal line has been drawn through the organization.

> The space on the right side of the line represents time devoted to vocational undertakings.
>
> The space on the left side of the line represents time devoted to management undertakings.

Close study of this diagonal line shows that:

> The foreman, a first line supervisor, devotes about 20 percent of his time to making low-level management decisions and the remaining 80 percent to technical or vocational decision-making.

> The chief executive officer, the top line management, devotes 90 percent of his time to making high level management decisions and the remaining 10 percent to making technical decisions.

Now, draw a series of imaginary horizontal lines through the diagram. These lines represent an individual's growth in the company. It is interesting to note that, as an individual moves up in the company, he will become more involved in management and the less in the vocation in which he started.

One of the most difficult decisions a man has to make is whether he really wants to become a manager. For if he does, as he moves up in the company, he will be using less and less of the maintenance skills he was taught and learned through experience and more management skills and tools. And when he reaches the top, he will probably not even be reasonably competent in the vocation in which he started.

THE MANAGING PROCESS

A man in the capacity of manager--whether as chief executive officer or foreman--accomplishes results through other people by using the same simple three-step process of:

Establishing objectives,
Directing the attainment of those objectives, and
Measuring the results.

Even though the same three-step process is used at all management levels, there will be a definite difference in the magnitude of the decisions that are made at each level. For example, using the positions of chief executive officer and foreman for illustrative purposes:

> The chief executive officer may decide - "We are going to buy a two million dollar overhaul facility."
>
> The foreman may decide - "We will spend $50 on a barrel of cleaner."

They are exactly the same kind of decisions, i.e. the decision to purchase. The difference is in degree.

There is no question, therefore, that almost anyone can be a good manager regardless of his level of management PROVIDING he knows the functions of a manager and exercises them properly within the limits of his authority. Most people have potential ability to manage. The problem lies in developing the ability to handle specific magnitudes of management decisions.

Unfortunately, and contrary to popular opinion, most managers are not born managers. Most managers are made through training and experience. Obviously, some may have more talent than others, but to become a good manager requires a great deal of training and study as well as practical experience. A <u>good</u> manager is, therefore, just as much of a "professional" as a doctor, lawyer or engineer.

As indicated above, there is a process of management which requires the recognition that the job is composed of three activities. In the three-step process:

> The manager must first determine what the objectives of his activity are.
>
> Second, he must organize his people and direct them so that they perform the activities necessary to attain these objectives.
>
> Finally, he must measure and evaluate the results of their efforts in order to determine how well his original goals were achieved.

Often, the final step (measurement and evaluation) results in modifying old or establishing new objectives. These, in turn, he seeks to attain by proper direction of others. In due course, he measures what has been accomplished, which again leads to the establishing of still further objectives. Thus the managing process is a continuous one. It goes on and on and is never finished.

Exhibit No. 2 illustrates the managing process graphically. The process is shown as a circular or continuous process by the rim of the wheel. Inside the rim are nine elements of managing placed by the step of the managing process they assist. All of them are activated by two additional elements of managing represented by the two inner gears—promote innovation and develop people—which keep the process of managing going.

The 11 elements of managing, listed in the order in which they are carried out, are:

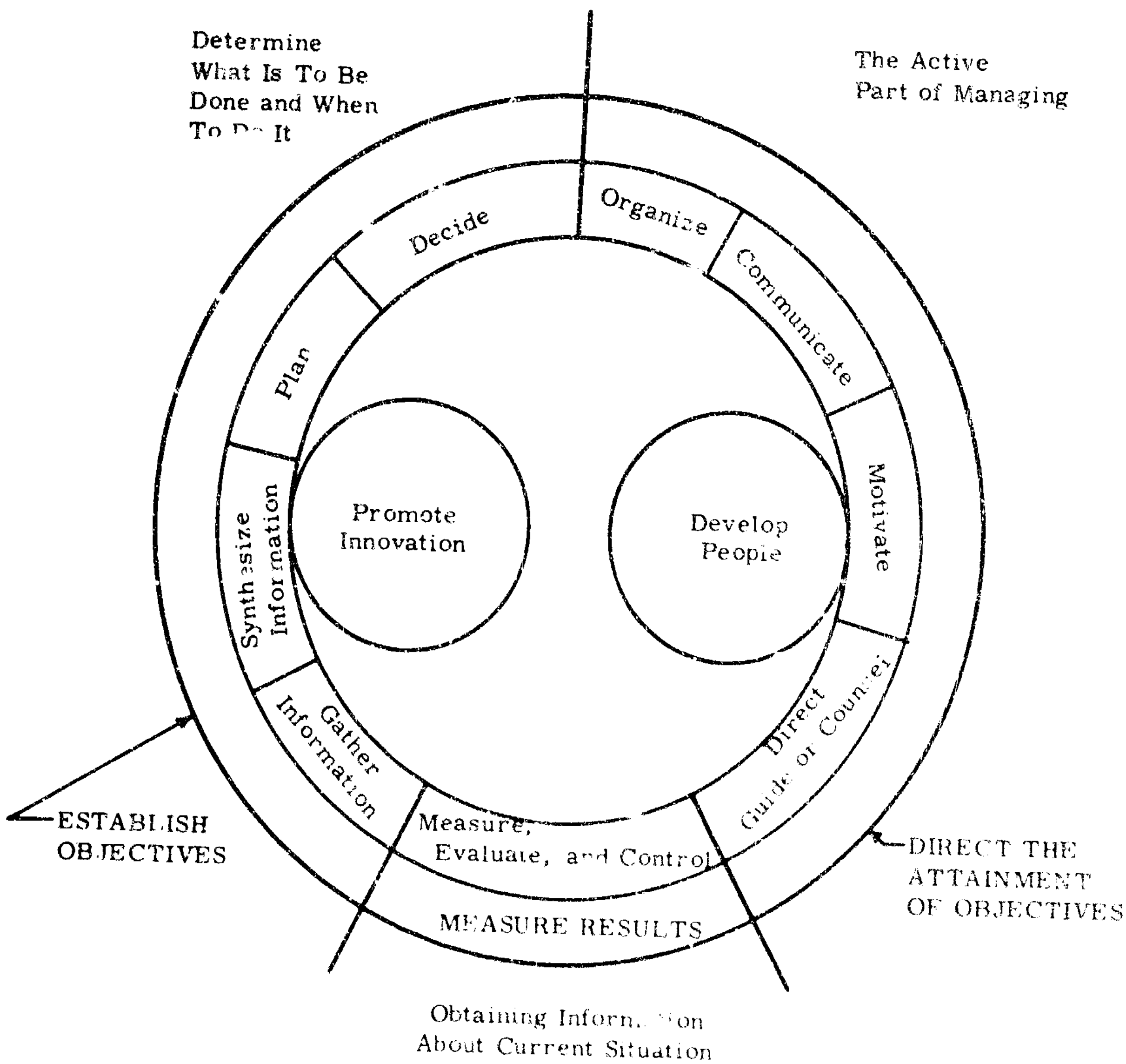
gather information;
synthesize information;
plan;
decide;
organize;
communicate;
motivate;
direct, guide or counsel;
measure, evaluate and control;
develop people; and
promote innovation.

<u>Establishing Objectives</u>

Every manager must have in mind definite objectives if he is to manage effectively. The more clearly and realistically objectives are established, the more likelihood they will be realized. There are four elements in this first of the three-step managing process:

Gather information - A clear understanding of the existing situation is essential before future goals can be realistically determined. The manager must constantly seek to keep himself fully informed by

Exhibit No. 2 - Elements of Managing



gathering all sorts of information from nearly every likely source by listening, reading and studying.

Synthesize information - It is seldom possible to get all the information on any situation of even moderate complexity. To fill any gaps that might exist, he must study the material at hand and fill in from his own experience, education, background and imagination.

Plan - With a good understanding of the current situation and probable future influences obtained by gathering and synthesizing information, it is necessary for the manager to plan what should next be done. During this phase, he will begin to formulate in his mind tentative objectives. Then he will consider various alternative courses of action by which the objectives might be reached. This planning, in turn, may cause him to revise his tentative objectives as he finds them too difficult or too easy to attain.

Decide - A good manager may or may not make up his mind quickly. If he has carefully taken all of the previous preliminary steps, the facts often lead to the correct decision.

Clear, careful thinking is necessary in establishing objectives. By establishing objectives, the manager decides what is to be done and when to do it.

Direct the Attainment of Objectives

The manager accomplishes the second step of the three-step process by using the following managing elements :

Organize - With few exceptions, the manager will expect to reach his objectives through the efforts of others. To organize for its accomplishment, he assigns the people and facilities, he assigns the duties and responsibilities, he delegates authority, and establishes reporting relationships.

Communicate - Next, the manager must tell his people what he wishes them to do. He explains the ultimate objective and what he expects each person to accomplish toward its realization.

Motivate - To inspire his people to want to achieve the desired results, the manager must motivate them. This calls for explaining the <u>why</u> of the project in terms of the interests of the individual and his group.

Direct, Guide and Counsel - If a man does not know how to do something--no matter how clear it may be to him and even if he agrees why it should be done--he will not be as effective as he should be. To make sure that his people know how to achieve the desired results, the manager must direct, guide and counsel.

These elements are considered the active part of managing. They are the elements that the manager is most conscious of performing and those that an observer of his activities can most readily recognize. They are employed in order to attain the objectives that were established by the use of the first four elements.

Measuring Results

To measure, evaluate and control is necessary if the manager is to be able to determine how effectively his plans are being carried out

and, in a broader sense, how effectively he is managing. There are many criteria which may be used and each of these will appeal differently to different people.

The element of measure, evaluate and control is a very important task in the task of managing. Without some form of follow-up, the manager cannot hope to manage effectively.

Driving Forces of the Management Process

Developing People -

One of the most important responsibilities of a manager is the development of the people he manages. It is his job to get results through others. Therefore, the more competent those others are, the better the results he will achieve. His own success will be proportionate to his ability to help others to become successful.

Promoting Innovation -

Promoting innovation is the second of the two driving forces of the entire management process.

The company that leads the way is the one that has the manager or team of managers never satisfied with the way things are. He constantly encourages people to seek new products, new services, and better ways of doing things. He acts as a dynamo at the center of the organization, radiating energy and enthusiasm for the new to all activity areas.

CHAPTER II - MAINTENANCE ORGANIZATION

INTRODUCTION

In order to attain objectives, an organization is a must. To establish a maintenance organization:

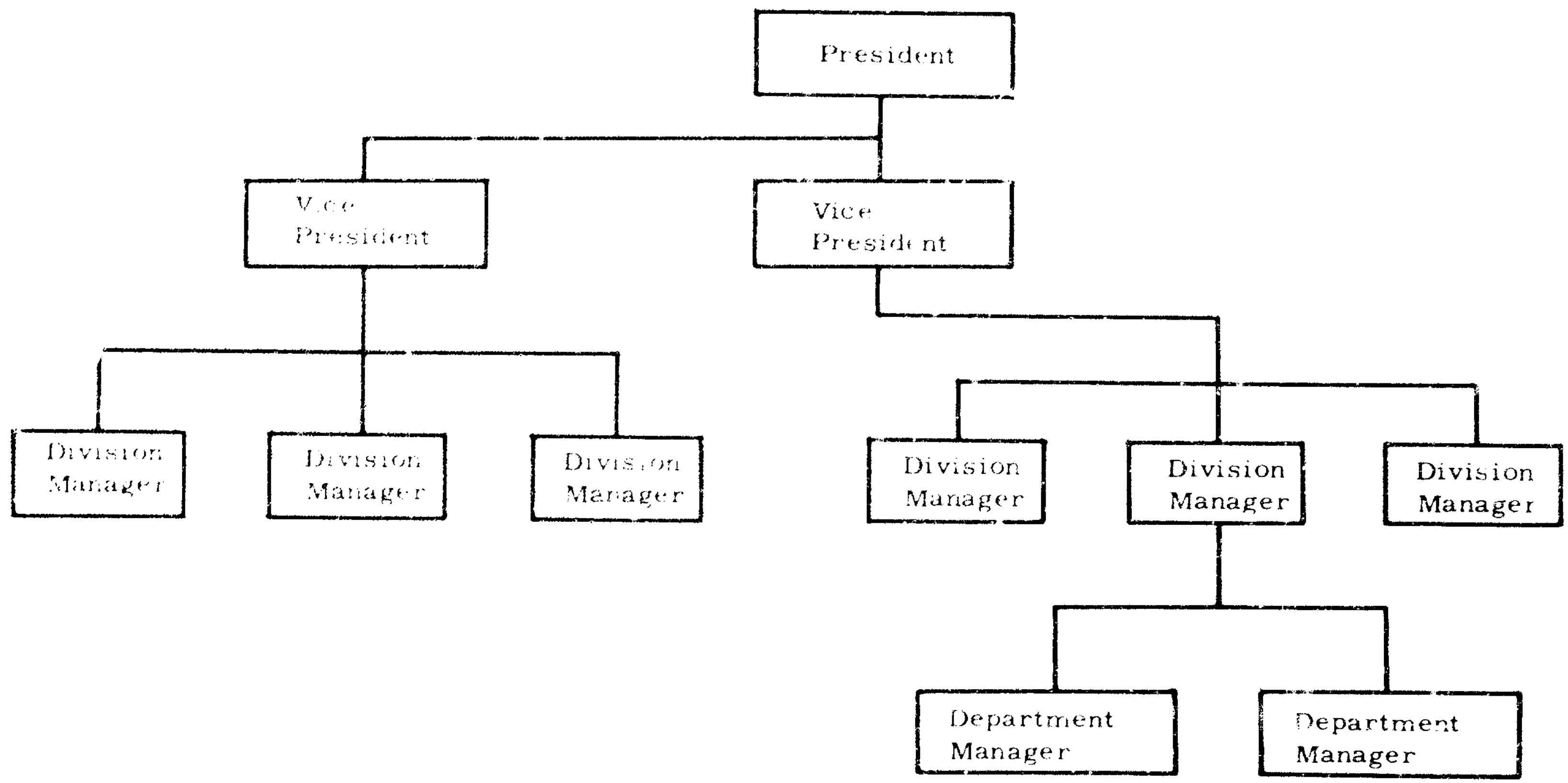
> People must be brought together.
>
> They must be assigned jobs.
>
> The work of each job must be related to the other.

ORGANIZATION CHART

Exhibit No. 3 illustrates one of the many different types of maintenance organization charts that are available. Being a communications device, it can tell many things. For example, it shows:

> First, who has the authority over whom. (Authority is the right to take action and give directions without securing permission from a higher authority). It is very easy to see that the president has the authority over the three vice presidents. The vice presidents have the authority over the division manager who, in turn, have the authority over the department managers, and so on.

Exhibit No. 3 - Basic Maintenance Organization Chart



Second, where responsibility is located. (The duties which an employee must carry out.) The president is responsible for the entire organization as well as the three vice presidents. The vice presidents are responsible to the president and also for the division managers under them and so on. So, responsibility appears to be a two-way street. Responsibility cannot be divided--it pyramids.

Authority, on the other hand, can be divided. When the president delegates to the vice presidents, he delegates authority to make decisions and also makes it clear that he is holding the vice president responsible for carrying out these decisions.

Third, the chart shows reportability. (The duty to get direction from, and report on activities to, a superior.) In its simplest form and in theory, the president goes to the vice president to get something done, the vice president goes to the division manager, the division manager goes to the department manager and so on. This concept of the flow of authority is correct, but not always efficient--particularly in a small organization. There are many instances when, for one reason or another, the president finds it desirable to talk with the department manager without going through the normal chain of command. This may be perfectly understandable and correct. However, because the department manager reports to the division manager, who reports to the vice president, who reports to the president and each one of these people are responsible to his respective superior, it is most important that each management level report to his superior those things for which the superior may be held responsible.

Fourth, the chart shows accountability. (The duty to obtain the best results for the total organization regardless of chain of command.)

JOB DESCRIPTIONS

No organization can get its job done without some kind of delegation. The president cannot do everything. He must delegate work to his subordinates. In some cases, managers may have a reluctance to delegate part of their work to subordinates because:

> They may thing no one will do it as well as themselves.
>
> They may not trust anyone else.
>
> They believe they can do it quicker and better than anyone else.
>
> They are trying to protect their jobs.

There may be cases where these and other reasons are justified. If so, then something is wrong. The one basic premise that must exist is having subordinates capable of doing the work delegated to them.

When work is delegated, it must be accomplished within the framework of:

> The legal structure, i.e. laws.
>
> A basic sense of right and wrong, i.e. morals or ethics.
>
> Company policy and procedure for decision-making.
>
> The financial requirements, i.e. budget.

When work is delegated to a subordinate, put the fundamentals of the job requirements in writing. They are too important to be left to memory. Putting them in writing means preparing a job or position description that contains:

The job function.

Duties and responsibilities.

Relationship of the job to other jobs.

CHAPTER III - OBJECTIVES

INTRODUCTION

Industry has used objectives and performance standards since the late 1800's. The original techniques were developed by pioneers such as Gantt, Gilbreth and Taylor. Since then, these original techniques have been improved upon and are now widely and successfully used in industry and government. Because their use has been so successful, several top managements are beginning to consider their application to many of the major activity areas within their companies such as maintenance.

Management consists of primarily determining and maintaining objectives and planning ways and means of attaining them. Objectives are prerequisites for a sense of direction without which any amount of effort may be wasted and dissipated in aimless or self-cancelling activity.

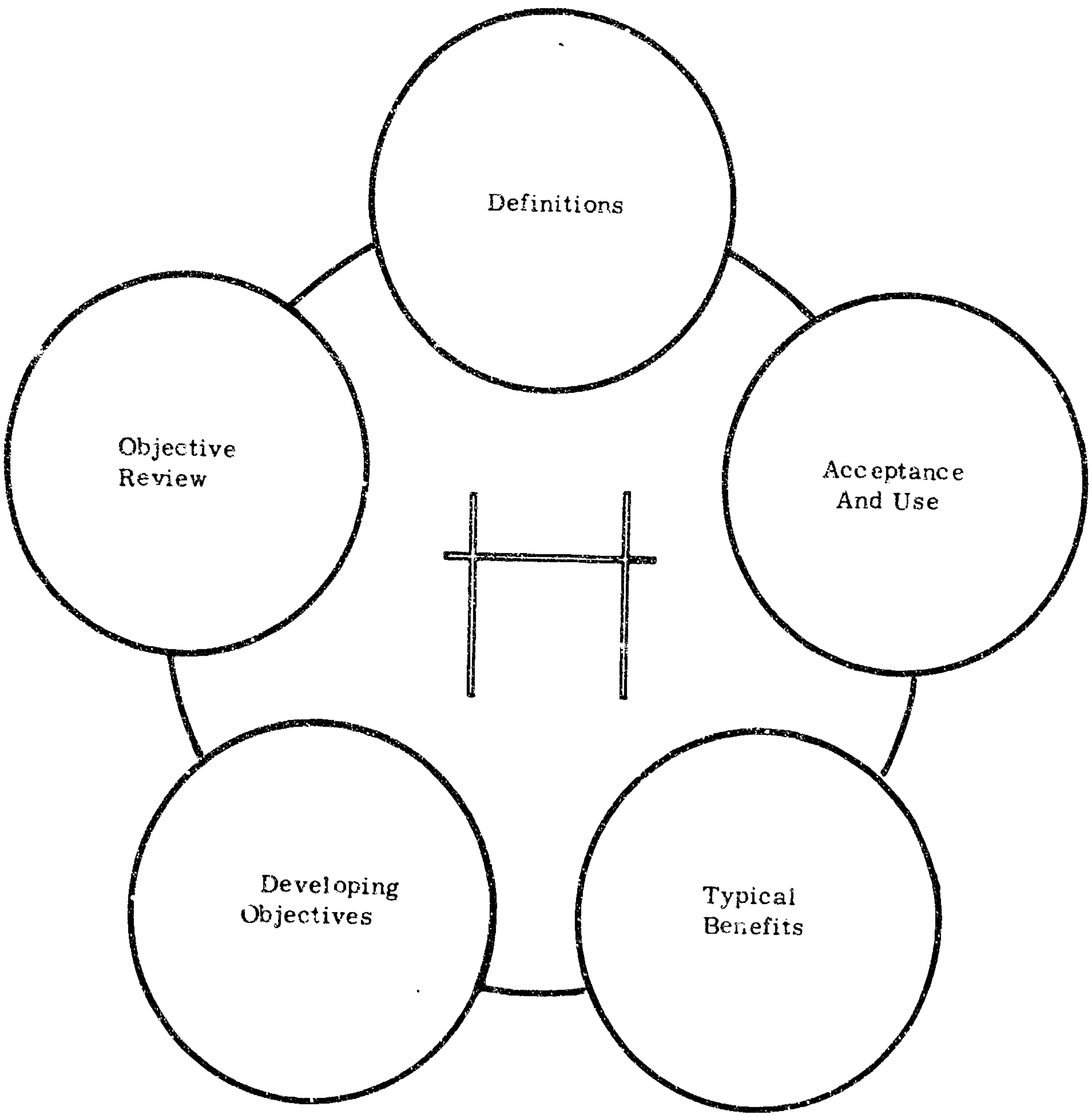
Refer to Exhibit No. 4 for an illustration of the development of the subject of objectives in this chapter.

DEFINITIONS

There are many different definitions of the word "objectives" — depending on the individual company. Here are some representative ones:

> "Management by objectives describes the management process whereby all work is organized in terms of achieving specified conditions (results) by set times. Implicit in the process is the requirement that the

Exhibit No. 4 - Objectives



pecified conditions contribute to achieving the broader objectives of the organization.'

"An objective is an aim or end of action, it is used as an aim or guide to intermediate decisions and actions."

"A job objectives is a statement of personal commitment to a specific accomplishment or result that is:

orientated to the mission,

measurable,

needed,

valuable, and

time-phased for accomplishment."

"An objective is a statement of the desired or needed result to be achieved by a specific time. It should be worthy of attainment, yet capable of achievement by superior performance."

Department objectives should be set knowing that both staff units and profit centers will receive credit for results where each has contributed toward the achievement.

Objectives should be set in those areas where results are essential to the continued success of the department.

Most companies that practice management by objectives usually set forth their policy in some kind of formal statement. There are

executives, however, that believe that their managers function more freely and fruitfully in the absence of formal policy. In other words, these executives believe that in an effective organizational climate, management by objectives does not need to be talked about, for it is being carried on anyway.

ACCEPTANCE AND USE

Many maintenance managers have objected to the idea that objectives and performance standards could be used in their type of activity. Their objections are similar to those expressed by managers in other fields for many, many years:

> Aircraft maintenance work does not lend itself to objectives and performance standards.
>
> Their activity was too small.
>
> Aircraft maintenance management was an art, not a science.
>
> Objectives and performance standards would decrease the flexibility of their present activity.

Some of these arguments have some validity--but not much. Once the concept is thoroughly understood, objectives and performance standards will be used in every aircraft maintenance activity. Perhaps not in the form described herein--but in one form or another.

Among the major reasons that management by objectives, or accountability management as some call it, fails in some companies are:

The failure to recognize that management by objectives is a complete management system and not a secondary procedure attached to some other system.

The underestimation of the amount of time and effort necessary to install the process.

The failure to understand and master each component of the process as it became necessary to implement each step.

The failure of management to understand and appreciate the process.

The lack of follow-up support for the process.

TYPICAL BENEFITS

The benefits resulting from the use of objectives vary considerably among companies. However, we have found a strong indication throughout our research that an investment in an objectives program is very worthwhile.

Several of the major benefits resulting from the use of objectives are:

Improvement in coordinated effort toward established corporate and department goals.

Improvement in individual performance as the result of objectives combined with performance standards and appraisals.

Improvement in understanding and team effort.

Greater unity of purpose throughout the system.

Creation of a more demanding, more highly charged system tone.

Closer coordination and cooperation.

DEVELOPING OBJECTIVES

The first step in developing objectives of any maintenance activity is to define the activity. In one way, defining the activity can tell the basic objective of the activity. Our studies and experience indicate that those companies which are fairly sophisticated in their approach to planning will start with such a definition or statement when they prepare to establish a program of management by objectives.

Top management usually develops this definition. This is because they are the only ones that have the broad knowledge of the company's capabilities and maintenance requirements.

This is, therefore, the process of determining the activity's "mission". By mission, we mean what the activity is (or will be in the case of a new activity) and what it seeks to accomplish. This mission may be expressed in terms of a formal statement, an expression of overall intent, or even a series of informal statements of the chief executive officer. Regardless of its form, most companies believe it desirable that its top management have a clear picture of what this activity is and what it is trying to do.

Second, after defining the framework in which they plan to function, management should state the activity's objectives or goals in very broad terms.

Third, within the constraints of these objectives, the various lower levels of management should be asked to state their objectives and plans that will contribute to the achievement of the next higher management objectives and ultimately the broad company objectives.

Fourth, the objectives of each management level should be reviewed by the next higher level and so on until they reach the chief executive officer.

Fifth, top management will review the objectives prepared by the various management levels to determine the manner in which their objectives meet those of the company.

Sixth, after this review, top management will request that each management level revise its objectives to meet the company's objectives more appropriately.

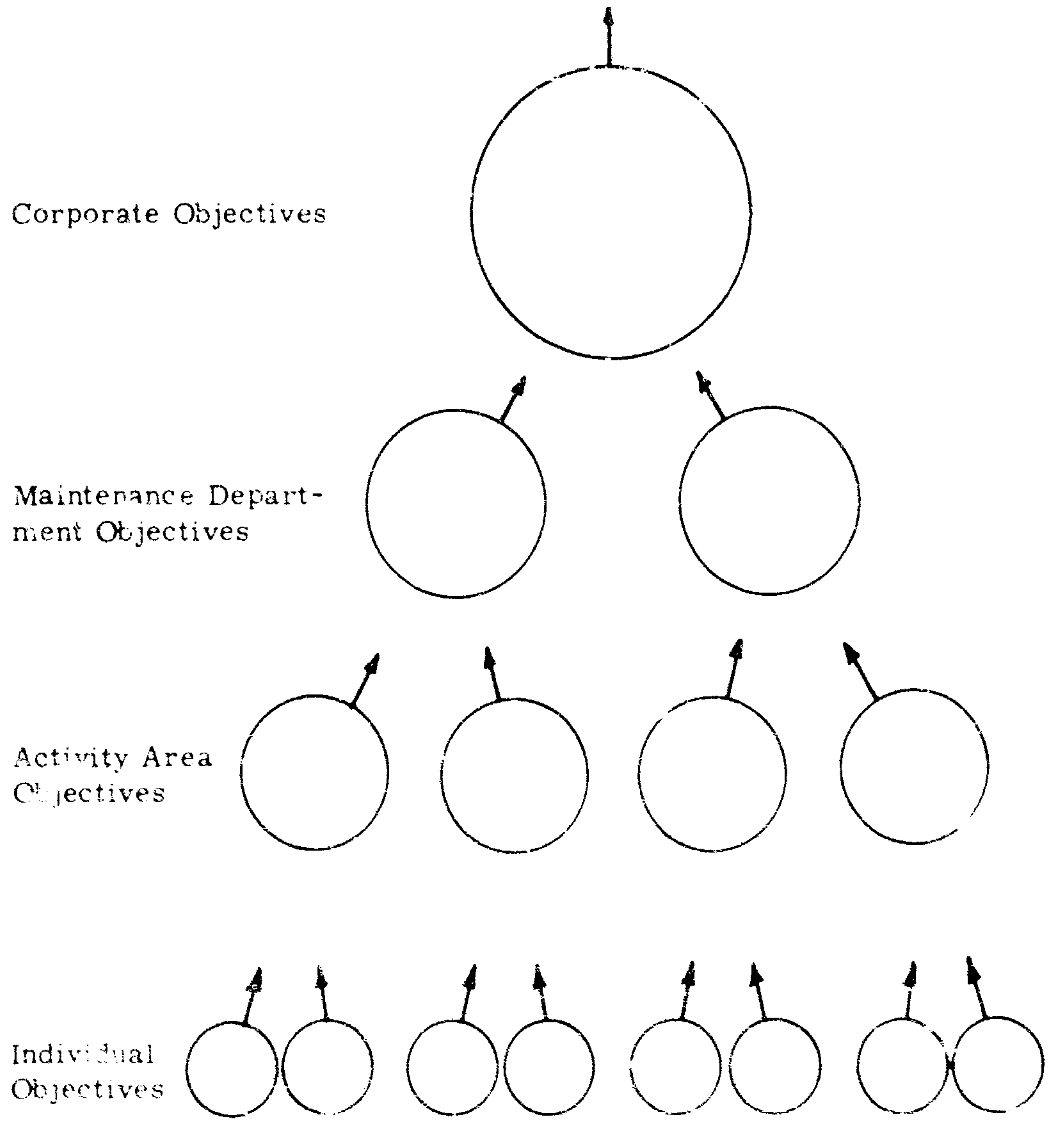
Seventh, after revision each management level's objectives will be resubmitted to top management for approval.

Many companies place emphasis on the systematic development and communication of objectives from the top of the organization down to the individual, i.e. the close tie between corporate long-term objectives, activity objectives and individual objectives. Refer to Exhibit No. 5. Each individual objective is tested to ascertain that it contributes to the objectives of the activity area. Next, activity area objectives are tested in terms of the system objectives, which are rationalized in turn with corporate objectives.

OBJECTIVE REVIEWS

Essential to the use of objectives is a "feedback" system to report back the results of the difference between objectives and the actual performance. As a result of any variances, the manager must

Exhibit No. 5 - Relationship of Objectives on Four Company Levels



decide whether effort should be increased within the existing framework or whether the objectives should be changed. If the decision is to change the objectives, the following is suggested:

> First, the superior reviews the corporate objectives to determine what changes, if any, should be made that might favorably effect the activity's objectives.
>
> Second, the superior sets a date for the review with the subordinate two or three days in advance.
>
> Third, the superior collects all available information indicating performance in relation to the objectives.
>
> Fourth, the superior and the subordinate review the performance against the objectives.
>
> Fifth, in every area where performance indicates a change in objectives is desirable, the superior in charge makes the appropriate changes and submits it to the subordinate.

DEVELOPING THE MAINTENANCE MANAGER

CHAPTER IV - PERFORMANCE STANDARDS

INTRODUCTION

The concept of standards of performance in business can be closely related to a golf game. In golf, until you know par for the course and for each hole, and in business until you have standards of performance, you really do not know what kind of job you have to do.

Every management has its own concepts of what constitutes satisfactory personnel performance in its maintenance activity. These concepts are standards of performance. They describe the conditions that will exist when an individual's performance is satisfactory in terms of quantity, quality, time and/or cost. When such standards are explicit, they can be of tremendous help to the individuals concerned and to the manager in producing the results desired by top management. As a result, an increasing number of companies are developing personnel performance standards to:

> Improve understanding of what is to be achieved; and
>
> Release the motivation which usually comes from fully understanding what is expected.

Very seldom will performance be up to standard in <u>every</u> aspect of any <u>job.</u> In addition, very seldom will conditions within any maintenance activity remain so stable that the standards can remain fixed. Therefore, whether personnel set out to bring their performance up to the level represented by a standard, or whether

changed conditions demand that standards be changed whenever personnel set out to improve performance or to make innovations, they are working in terms of meeting objectives.

Standards of performance, even though not written or articulated, do exist for all jobs in any maintenance activity. Every superior has more or less of an idea of what results he expects from his subordinates and, thus, evaluates results for salary or promotion purposes. Every subordinate has an idea, not necessarily conforming with the superior's idea, as to what results are expected of him. It is most desirable, therefore, that explicit standards of performance be defined and established. If they cannot be defined--if they cannot be measured--then perhaps the job should not be done at all

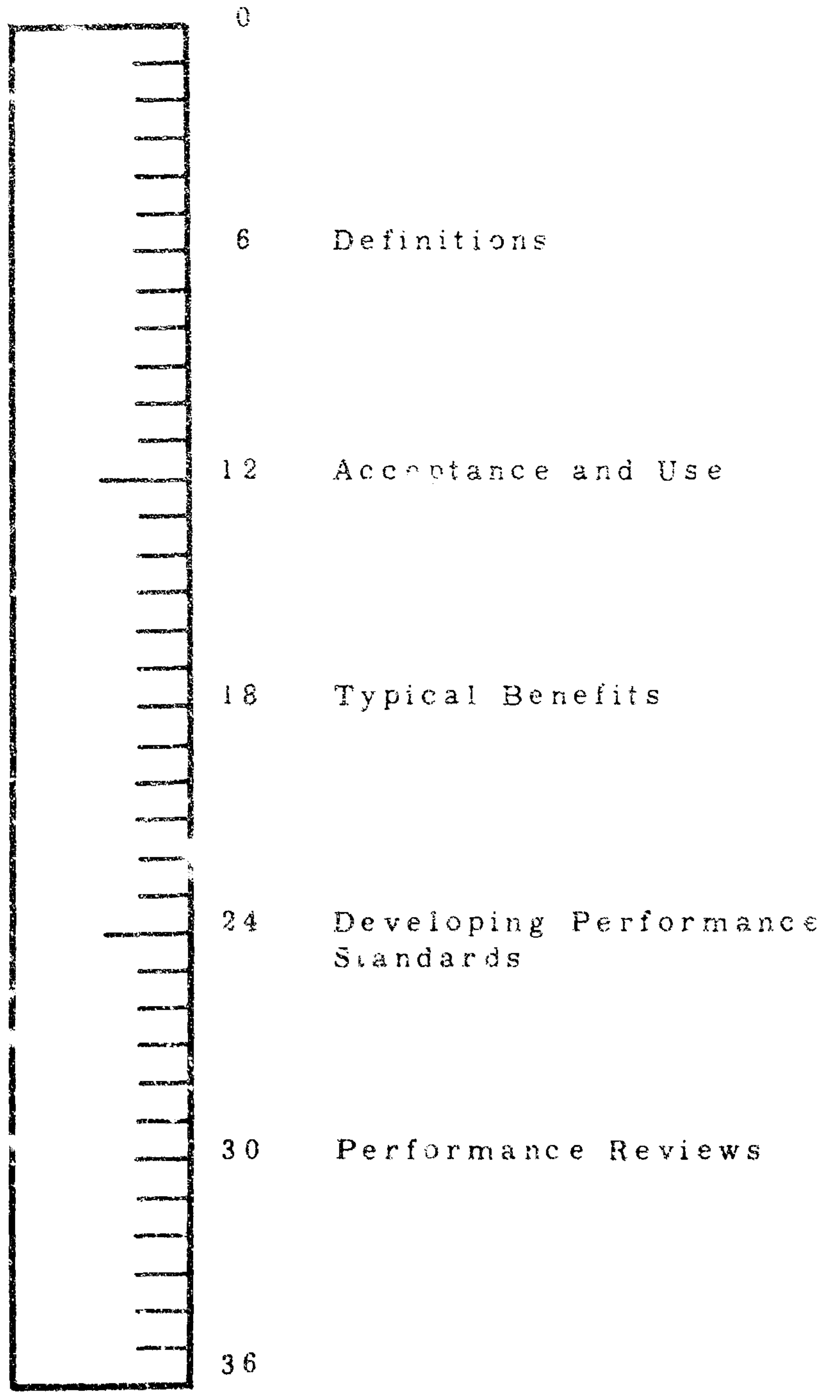
Refer to Exhibit No. 6 for an illustration of the development of the subject of performance standards in this chapter.

DEFINITIONS

Some companies that have set up formal standards of performance for the personnel in their maintenance activities often include them in a policy, systems and procedures manual.

> A performance standard (sometimes called a job standard) is a statement of conditions that will exist when a job is satisfactorily done. This job will have been satisfactorily performed when the following results are obtained. . .
>
> A performance standard emphasizes results; it makes a person accountable for the results of what he does. It is a statement of what constitutes adequate work.

Exhibit No. 6 - Performance Standards



Standards of performance say how rather than what. (A job description defines responsibility--what is to be done. A performance standard specifies how well the job is to be done.) They spell out the targets or expectations of a man and his superior in connection with a given job. They list conditions or effects which are either wanted or unwanted in terms of quantity, quality, timeliness, and/or cost. Through analysis of each major job segment, a series of standards or specific goals for performance is developed. These can be used later to judge whether the total job is being performed satisfactorily. Meanwhile, they represent an agreement on the goals of the job holder.

STANDARDS

Standards for Company Performance

Every manager of a maintenance activity will agree that the performance of his company is being judged by:

- potential and actual purchasers of stock,
- banks,
- the financial community,
- purchasers of the company's products or service,
- employees,
- the company's management, and
- the community.

Each one of these groups may have its own method of and standards for judging the company's performance, but you can be sure it is being judged.

Standards for the Maintenance Activity

It is also reasonable to assume that the performance of the maintenance activity is also being judged by certain individuals or groups within the company by:

potential and actual users of the activity,

those concerned with corporate costs, and

the company's management.

Here, as in the case of the company's performance, each one of these groups has its own way and standards for judging the activity's performance. And, again, you can be assured it is being judged.

Standards for the Individual

As the company and maintenance activity within the company are being judged by certain groups interested in their performance, each individual within the company is probably being judged by his superior who is also interested in performance. And this includes the manager of the maintenance activity. Therefore, if the activity manager is going to be judged, it would certainly appear reasonable that he should be completely aware of the standards by which he is being judged. As a matter of fact, if at all possible, it would be most desirable if he had a hand in establishing these standards.

TYPICAL BENEFITS

As for objectives, the benefits resulting from the use of performance standards vary widely among companies. However, listed below

are several representative benefits that any company can expect to receive from preparing performance standards:

Promote understanding between the superiors and subordinates;

Focus attention on results rather than on methods or personalities; identify the areas needing improvement and provide a key tool for individual development;

Promote balance in job effort;

Help managers become more objective and less subjective;

Increase motivation;

Improve self-direction and self-control;

A sounder basis for compensation discussions;

Facilitate self-appraisal and can provide a sense of achievement; and

Provide a basis for performance review.

In summary, performance standards provide:

Before-the-fact challenge and commitment;

During-the-fact control; and

After-the-fact appraisal or review.

CHARACTERISTICS

Performance standards identify the conditions or effects wanted or not wanted in terms of quantity, quality, time and/or cost focusing on:

> Results - Whenever directly observable.
>
> Symptoms - Whenever results are not directly observable, i.e. turnover rates or absentee rates might be a symptom of morale.
>
> Methodology or casual action - When results cannot be directly or indirectly measured in the short run, the standard may identify the methods used or the actions to be carried out to increase the probability of good results.

Performance standards should be devoid of vague or ambiguous language. Terms such as reasonable, generally, approximate, occasionally, few, optimum, as necessary, etc. should not be used.

Standards should be realistic and attainable. Most employees should be at a satisfactory performance level most of the time.

A performance standard does not represent an outstanding performance or the ultimate goal. It should be the baseline from which excellence is to be measured.

Performance standards should cover, and at lease initially, only the major job responsibilities.

Standards should be current--regularly reviewed and revised as necessary.

Performance standards should be jointly developed and specifically accepted by both the superior and his subordinates.

Types

There are two types of performance standards--objective and subjective.

Objective -

There are three kinds of objective performance standards--engineered, historical, and comparative. The engineered standard is very widely used. It can be best explained in terms of production. For example, where a machine is involved, the mechanic will have done a good job when he has overhauled three units per day.

The second type of objective standard is the historical. This, too, is very popular and can be best explained in terms of history. For example, we want to know how many units the mechanic is overhauling today compared to a year ago.

The third type is comparative. This is where an activity's performance is compared against the trade or perhaps even a competitor's performance. For example, a mechanic will be doing a good job when he is overhauling units within five percent of the industry average.

Subjective -

Subjective standards usually have to do with the relationship between a superior and his subordinate. Many superiors demand certain elements of performance

from their subordinates without having firm basis for them--sometimes on the basis of bias. If such standards are required, put them in writing. Most of the time they will look pretty foolish in black and white.

Categories

Regardless of the type of performance standard, objective or subjective, there are three broad categories--positive, negative and zero--into which any standard will fall.

Positive -

The positive standard is one that expresses a direct statement of what is desired in positive terms. For example, a mechanic will have done a good job when he increases the number of overhauled units to three and one-half a day. This is a positive statement, something that can be measured.

Negative -

The negative standard is one when the foreman does not know what he wants, but he does know what he does not want. For example, the mechanic will have done a good job when no more than one of his overhauled units are rejected by the inspector each week. This may seem strange, but often quality can be measured in negative terms.

Zero -

This category of performance is where zero performance is wanted in an area. For example, a mechanic will have done a good job when none of his overhauled units have been rejected by the inspector.

DESIGNING PERFORMANCE STANDARDS

The environment in which and purposes for which performance standards are designed can have a great influence on their effectiveness. If they are to be used as a tool for personnel development--fine, go ahead with the program. If they are to be used as a club with which to beat personnel--forget the entire program.

There are three basic ways of designing or drawing up standards.

> The first, and probably the best way is for the subordinate to write his own standards and submit them to his superior for approval.
>
> The second, and next best way is for a group of people with exactly the same job to write a set of standards for all of them.
>
> The third, and least desirable way is to have the superior write the standards and give them to the subordinate.

DEVELOPING PERFORMANCE STANDARDS

There are several methods of developing performance standards. The following is one that we have used quite successfully:

The first step in developing performance standards for a maintenance activity is to explain the concept and establish an appropriate climate. No one will willingly participate in the construction of a club with which he will be beaten. For example, even without performance standards, the subordinate's performance is reviewed and evaluated by the superior. It is to the subordinate's advantage to participate in the determination as to specifically how his performance will be evaluated.

Ideally, start at the top of the company. In any event, the superior should develop and secure approval of his own performance standard as far as the activity is concerned. If the subordinate knows that his superior and the president are committed to performance standards, he will participate more willingly.

Next, if job descriptions exist, they can be used as a guide in writing performance standards. Note the word guide was used because the purpose of job descriptions is somewhat different than performance standards. The job description covers all elements of a job while performance standards cover the specific results desired for a given responsibility. From the job description, the kind of jobs or duties to be emphasized can be extracted and the results expected spelled out.

Third, the subordinate should propose a draft of the performance standards to be reviewed by his superior. For each function or responsibility, list in precise terms--results, symptoms, methods or actions, in terms of quantity, quality, time and/or cost.

Fourth, the subordinate's draft proposals should be reviewed by the superior and discussed, keeping the following in mind:

Most individuals tend to set standards too high--at least in the areas of these special competence or interest. Standards accepted should be realistic.

If standards proposed by the subordinate do not meet the requirements of the superior -

Negotiate upward, but realistically, since the subordinate's acceptance and commitment is essential.

Develop program so necessary results can and will be attained.

Reorganize either as to responsibility or personnel.

Fifth, request that the subordinate revise the draft in accordance with the discussion.

Sixth, discuss, review and the standard as effective for a "trial" period.

Seventh, at the end of the trial period, review actual performance against those specified in the standard.

Eighth, request that the subordinate submit a revised standard in light of the experience gained during the trial period.

Ninth, discuss, revise and accept the new standard for the period ahead.

PERFORMANCE REVIEWS

General

A performance review can be defined as a detailed and comprehensive review or appraisal of a subordinate's performance by his superior with the major objective to improve the subordinate's performance. Properly organized and implemented, such a program can be a very effective tool for not only improving personnel performance, but also a major factor in helping the company reach its ultimate objective which is usually to make a profit.

Study of Performance Review Programs

During the past 12 months, we have conducted an extensive study of performance review programs of several major companies. Here are some of the results of our study:

> Day-to-day contact and random coaching is fine, but it is not a substitute for the periodic, more complete systematic performance reviews held from six to nine-month intervals. However, properly handled, day-to-day contact does have some definite advantages:
>
>> First, a subordinate will accept one or two suggestions for improved performance much more readily than he will in the larger numbers that are generally the result of the annual comprehensive

performance review. There is no question that subordinates are more prone to reject criticisms as the number of criticisms mount.

Second, in the day-to-day contact feedback to the subordinate can be very effective because the time lapse between performance and feedback is small.

Goal setting, not criticism, should be used to improve performance. When a superior and subordinate together set goals to be achieved, rather than merely discuss needed improvement, the performance is far superior.

Separate reviews should be set for separate purposes. It is completely unrealistic to expect that a single performance review will satisfy every need.

One Performance Review Program

Briefly described, one of the most successful performance review programs that we studied calls for periodic meetings between the superior and his subordinates. During these meetings, progress on past goals is reviewed, solutions are sought for job-related problems and new goals are established. The intent of this method is to create a situation in which superior and subordinates can discuss job performance and needed improvements in detail without the subordinate becoming defensive.

This approach differs from the traditional performance appraisal program in that:

There are more frequent discussions of performance.

There are no summary judgements or ratings made.

Wage and salary action discussions are held separately.

The emphasis is on mutual goal planning and problem solving.

As far as frequency is concerned, these performance reviews are held more often than the usual annual or semi-annual appraisal interviews and they are not scheduled at rigidly fixed intervals. Usually at the conclusion of one planning session, the subordinate and superior will set a date for the next review. Frequency will depend on the nature of the subordinate's job and the superior's style of operating. Sometimes these discussions are held monthly--sometimes every six months.

The superior and the subordinate do not deal in generalities in these discussions. They consider specific, objectively defined work goals and establish the yardstick for measuring performance. These goals stem, of course, from the broader activity objectives and are defined in relation to the individual's position in the activity.

Interviews between superior and subordinate should be on a man-to-man basis rather than a father-to-son basis. This is highly desirable because it is much more effective if the subordinate will take the initiative when his performance is being reviewed. Thus, it is quite natural for the superior to fall into the role of a counselor. This, in turn, will probably result in a problem solving discussion.

The steps involved in a performance review are similar to those involved in establishing objectives. They are:

First, the superior sets the date for the review with the subordinate two or three days in advance.

Second, the superior collects all available information indicating performance.

Third, the superior lets the subordinate review his own performance, point by point, against the standard.

Fourth, the superior keeps all questions and comments non-critical until he is sure he understands the situation from the subordinate's point of view.

Fifth, if the superior agrees with the subordinate's analysis, he should say so. If not, he should so state clearly with reasons.

Sixth, it is not necessary to have the subordinate agree that he is primarily responsible for anything less than a satisfactorily situation--only that he has, in some way, contributed to it.

Seventh, for every area where performance is sub-standard, a specific program should be agreed upon by the superior and the subordinate to improve performance. The subordinate should be asked to propose a program for improvement--a second grade program to which he is committed is likely to be more effective than a first grade program imposed by the superior. If the superior must make suggestions for approaches, give the subordinate alternatives and let him choose the one he feels will improve the situation.

Eighth, the superior should ask if the performance standards should be revised in any respect and have the subordinate propose revisions.

Ninth, the superior should ask the subordinate if anything he is doing or not doing is making the sub-ordinate's job more difficult.

Tenth, any commitment to a program to improve performance should be confirmed in writing and made a part of the next performance review.

Procedures Which May Cause Performance Reviews To Be Less Effective

Salary reviews should not be held simultaneously with performance reviews. If salary is part of the discussions, the subordinate's attention will be focused on salary as all important.

Detailed records of the performance review should not be kept for personnel files because:

> Some superiors may be less than totally honest on papers for the files.
>
> If the subordinate feels a permanent record is being made of any shortcomings, he will be less than frank.

Too much praise has little or no effect on improving performance. Criticism itself brings out defensive reactions that are essentially denials of responsibility of poor performance.

DEVELOPING THE MAINTENANCE MANAGER

CHAPTER V - DEVELOPMENT PROGRAMS

INTRODUCTION

To strengthen weaknesses and develop the strengths in each individual's performance that were covered in the performance review, management should provide development programs that are man-centered based on:

The real needs of the individual manager.

The requirements of the job.

Getting full value from the time and money expended on the project.

PROGRAMS FOR THE PRESENT AND FUTURE

In the process of conducting the performance review with his subordinate every superior should have a good idea of those areas in each individual that need further development. This is important because:

There are areas in their present jobs that need to be taken care of.

There are areas that apply to these future jobs that need to be taken care of.

In reviewing all of the individual areas about each man that require attention, it is very important to analyze and group them appropriately into such factors as planning, financial, purchasing, etc. An individual should not be developed on "nit-pickin" items but in broad areas that will apply in not only his present manager's job, but also as he may move up to vice president of maintenance and even as president. For example, once he is a planner, he will always be a planner. The only thing he may not know is how to plan in different magnitudes, but this he can be taught.

Superiors must also remember that one subordinate needs development in his present job, another for his future job, and still another for both his present and future jobs. In other words, development programs must take care of the future as well as the present.

INDIVIDUAL

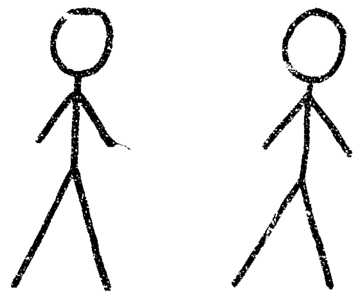
There are a great many ways that a superior can start a development program with a subordinate. One of these is referred to as the individual developer-developee, trainer-trainee or any other appropriate phrases.

Refer to Exhibit No. 7.

Coaching and/or Counseling

In this method, the superior tells the subordinate what is to be done, The superior can show the subordinate how to do something, he can tell him how to solve a difficult problem. This is usually called on-the-job training. It has been very effective in the past and will continue to be so in the future.

Exhibit No. 7 - Development Programs: One-To-One



Coaching and/or Counseling

Job Rotation

Guided Experience

Reading

Special Assignment

Job Rotation

In this media, the man is rotated through a series of different jobs over an extended period of time--as much as two years. This is similar to the coaching and/or counseling technique but gives the man greater exposure.

Guided Experience

A variation of the job rotation is the guided experience technique except that instead of two years, this media represents about two or three months. This technique is particularly helpful in getting several managers opinions of the subordinate and finding where the man may best fit into the organization.

Reading

While reading is not strictly an individual relationship, it is extremely important and definitely must be considered. Basically, men develop themselves. A course in guided reading can be very effective.

Special Assignment

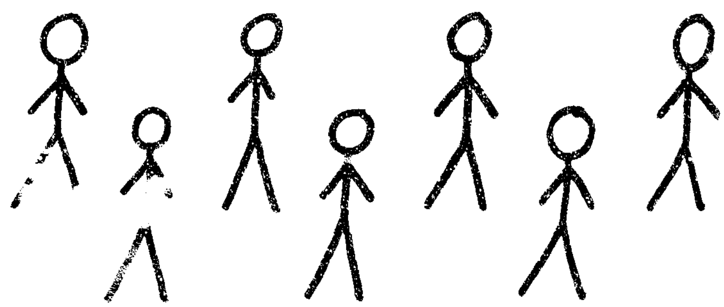
To determine an individual's aptitude for some particular area, it is possible to put him on a special assignment.

GROUP

There are many cases when it is neither economical nor efficient to use the individual type of development program but rather the group type where several men participate at once.

Refer to Exhibit No. 8.

Exhibit No. 8 - Development Programs: Group



Courses and Classes

Committee

Role-Playing

Case Studies

Task Forces

Brain-Storming

Courses and Classes

The course and class type program is one of the most popular. In this group media, what the instructor says is important, but the interchange of ideas among the members of the group is equally if not more important.

Committee

Within a company, appointing a man to a committee is very effective. When he joins a committee, usually neither he nor the committee make final decisions. But what does happen is that he assumes the burden of making recommendations to the men who do make these decisions. If he makes good preliminary decisions and participates in making good preliminary decisions, he will be preparing himself for the day when he will be making the final decisions himself.

Role-Playing

Role playing, properly handled, can be a very interesting and very effective way of people learning a great deal about themselves.

Case Studies

In our opinion, case histories are the most interesting and effective group media. In this way, people can be given a set of circumstances and ask them to analyze what has happened. Case histories are very effective in training people to distinguish between good decisions and bad decisions.

Task Forces

The task force media takes a man out of his usual role and places him, along with several other men with different jobs, in a group

to solve a particular problem. After being subjected to several other different viewpoints and seeing how he reacts to them, he will be in a position to do a better job once he steps back into his normal organizational role.

Brain-Storming

In this medium a group of men are able to sit down and just let themselves go and suggest all possible solutions to a particular problem. Following the session, it may be possible to use some of these solutions in solving the actual problem.

TRENDS

There are some very interesting trends taking place in management development programs. A brief look at some of them might be helpful.

Man-Centered Programs

In this type of program, the performance review is used as a base. Specific, not general qualities in the individual are developed over a long period. In this manner, each person will be developed on an individual basis.

Develop those people that want to be developed in the ways that they can be developed. There are many people having emotional limitations, some may have physical limitations. The main point is that everyone that can be developed--should be. But on an individual basis.

Inside and Outside Training

If a person is to be developed for a specific quality, do it inside the company. If a general quality is to be developed, it is quite possible that some outside organization may be better equipped to do this.

Job Correlation

People should be encouraged to study or train in some areas perhaps not directly but only indirectly related to their jobs. You can never tell when a knowledge of purchasing or accounting might be of help to a maintenance manager.

Study

Encourage regular study along with good study habits. If a man can develop good study habits, he has come a long way as a self-starter. And because a man develops himself, a self-starter has made a major step forward in his own development as a manager.

CAUTIONS

In preparing development programs for the individual manager, there are several words of caution to keep in mind:

> In many ways, people are pretty much alike. In many more ways, they are different. Therefore, do not make your development programs alike.
>
> Keep your program simple. They do not have to be a "big deal" if they are done properly.
>
> Money. Development programs require money. Keep an eye on it. There may be many things you would like to do that the budget just will not allow.
>
> Do not just overcome weaknesses--DEVELOP STRENGTHS in your people. Certainly weaknesses should be overcome whenever possible, but developing the strengths of your people can be equally, if not more, important.

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There are areas that apply to these future jobs that need to be taken care of.

(Continued)

SOURCE AND REFERENCE MATERIAL

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FACTORS TO CONSIDER IN DEVELOPING NEW SYSTEMS EFFECTIVENESS MEASURES

John P. Foley, Jr.
Training Research Division
Air Force Human Resources Laboratory
Wright-Patterson Air Force Base, Ohio

Typical systems effective measures are accuracy of system (to perform mission), reliability, cost, turn around time, down time, time to do job (mission), and spare parts usage. There is no doubt that each of these measures tell us something important. And in a general way they indicate whether or not the man machine system is living up to our expectation. But do they tell us enough?

From available evidence it is highly possible that such measures are masking some expensive defects and weaknesses in the performance of the human maintenance subsystem. Tolerances or "fudge factors" that have been used during the system's design probably compensate for these weaknesses. For example, we may be accepting as normal excessive spare parts consumptions, maintenance actions, down times, and numbers of maintenance technicians. Such weaknesses would only become apparent when the systems tolerances or fudge factors were not sufficient to cover them.

The inability of operator personnel to operate a new system becomes apparent very early in a systems evaluation. However, the inability of maintenance personnel may not become immediately apparent during system evaluation, if ever. The overall weaknesses of the human maintenance subsystems may not be attributed to the maintenance technicians but to something else.

INABILITY TO TROUBLESHOOT

Finucane (1966) reports a serious spare parts shortage that was caused by the inability of maintenance technicians to troubleshoot. A few years ago the Army had a shortage of engine parts for tanks and trucks. A thorough investigation of the problem indicated that a majority of the parts that had been discarded as defective were still

good. A series of task performance tests were developed and given to a large number of Army engine repairmen. Although they had been rated as fully qualified, these task performance tests indicated that many repairmen could not troubleshoot engines. They were therefore replacing parts until the engines became operational.

At about the same time the Air Force Aero Propulsion Laboratory obtained over 100 cards for an electronic system from an Air Force depot for one of their research projects. These cards had been determined to be defective by depot personnel. A thorough check of these cards indicated that approximately 40% of them were still good.

During a recent field survey of electronic maintenance technical data sponsored by our laboratory (Folley and Elliott 1967), 12 Air Force Bases were visited. The following statement was made by the authors concerning troubleshooting and repair of the electronic equipment.

> It was apparent during field observation of troubleshooting and repair that many technicians frequently proceed on unverified assumptions, use incorrect logic, and come to (erroneous) conclusions on the basis of patently incomplete evidence. Often information about the state of signals inside the equipment obtained early in a troubleshooting sequence is forgotten before the end of the sequence--leading to a faulty conclusion about the location of malfunction. Not once was a technician ever observed to write down that information he had obtained from his troubleshooting checks.
>
> The consequences of such thinking are frequently slight, causing in some cases, an additional testing reading to be made or an additional $5.00 tube to be replaced with a consequent delay of a few seconds or minutes. However, if it requires 2 hours or more for the technician to find the Federal Stock Number of a component, as it too frequently does, the time consequences are more serious. Further, an error may result in the replacement of an item costing thousands of dollars with time consequences which result in an entire airplane failure to go on alert status as scheduled. One such situation was described by a technician. Another such situation was averted on the A3A system of the B-52. In the latter case, a major assembly was erroneously identified as containing the malfunction. When co-author Elliott was told that approximately 8 hours would be required to change the assembly, he told the team of technicians

(one seven and two five levels) that the evidence pointed to a different unit. On restatement of the evidence and re-examination of the logic, they revised their conclusion and replaced the unit indicated by the author. This cleared the trouble.

INABILITY TO USE TEST EQUIPMENT

The maintenance technician usually must use test equipment for gathering information about his system while he is troubleshooting. He also must use his test equipment for equipment checkout procedures and for such tasks as aligning, adjusting and calibration of systems. There is considerable evidence to indicate that many technicians cannot use their test equipment properly. Several years ago, the Navy made a rather extensive study of the test equipment ability of electronic technician of various grades. (Anderson 1962). The study indicated that complete mastery was not demonstrated in any test equipment by any grade group in his samples. (See Table 1).

TABLE 1

Percent of correct measurements for each type of test equipment in a Navy study (Anderson 1962) and an Air Force study (Folley, etal. 1968).

Type of Test Equipment	Number of Activities	Percent of Correct Measurements	
		Navy N = 415*	Air Force N = 30**
Multimeter (VOM)	7	73.5	51.7
Vacuum Tube Voltmeter (VTVM)	4	63.0	76.6
Signal Generator	4	57.1	64.3
Oscilloscope	6	32.0	-

*Sample included 68 chiefs, 55 first class petty officers (PO' s) [illegible] second class PO' s, 131 third class PO' s and 95 seamen.

** Sample included "5" and "7" level, mostly staff sergeants and technical sergeants.

These overall results are startling enough but a further diagnosis of these results uncovers some very important weaknesses. Only 10 percent of the sample were able to make amplitude readings using the oscilloscope. You might say that they are in the habit of making voltage readings with a VOM or VTVM instead of oscilloscope. But only 48.0 percent of the same made correct AC measurements using the VOM, and only 60.6 percent using the VTVM.

Table 1 also presents information during a more recent Air Force study (Foley et al, 1968). They found very similar results using a smaller sample of experienced Air Force technicians.

Such results become even more startling when considered in the light of overall job success. Consider again the results of the Navy test equipment study as applied to a rather simple electronic troubleshooting problem (see figure 1).

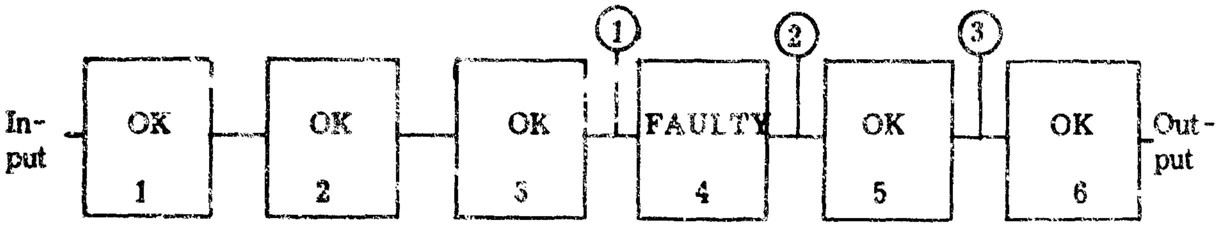

Figure 1. - Block diagram of a six stage electronic system with stage 4 faulty.

If a technician solved the between stage problem in the least possible number of steps, he would

1. Set up his signal generator and inject a signal at the input.

2. Using the split-half technique he would, set up his oscilloscope and obtain a pattern at 1 and 2. He would thus determine that stage 4 was defective.

As a best case, suppose that he determined that a resistor was defective in stage 4 using only one VTVM DC voltage reading and one VTVM resistance reading. Applying Cotterman's (1967) probability procedures, the probability that the best category technician would perform the signal generator and oscilloscope operations (for between stage troubleshooting) accurately the first time would only be .008 (p_{BS}).

$$p_{BS} = p_{SG} \cdot p_{OSC} = .010 \cdot .477$$

The probability that he would perform the voltage and resistance checks (for within stage troubleshooting) accurately the first time would only be .677 (p_{WS})

$$p_{WS} = p_{DC} \cdot p_R = .794 \cdot .853$$

The probability that he would obtain both the between stage and within stage information accurately the first time would therefore be .0032

$$p_T = p_{BS} \cdot p_{WS} = .008 \cdot .677$$

If he used a scheme that required more test equipment indications the probability of first time success would of course be still less. For example if he obtained 3 oscilloscope patterns, 6 DC Voltage readings and 3 resistance readings, the overall probability would decrease to .0005.

POOR CRAFTSMANSHIP

Another area of possible deficiency is in the use of handtools. This weakness seems to be quite common. Folley and Elliott (1967) report the following:

> Related to the problem of sloppy thinking is the problem of sloppy workmanship in repair. Wires and components burned by soldering irons were observed frequently, as were many electrically sound (at least temporarily) but physically poor solder joints. On one occasion, the authors detected nuts and bolts loose in the bottom of a radar modulator unit ready for installation in the aircraft. Though the shops themselves are typically kept clean by the technicians, repaired items leave the shop containing dirt and debris.

Such lack of quality in maintenance tasks can have dire consequences in any system. If a repairman replaces three components instead of one in solving a troubleshooting problem and in so doing makes several poor solder joints, he is injecting future troubles that will not be counted against him now. These will of course appear later in decreased systems reliability and will give the technician more opportunities to cause more secondary damage. Poor use of test equipment can also result in this type of damage. During checkout

procedures the technician can make a wrong meter reading or a wrong oscilloscope reading. He concludes that this is a symtom of trouble and replaced several components needlessly giving him another opportunity to cause secondary equipment damage.

I am sure that we have some sort of quality control for all parts that make up our machine subsystems, but we seem to take the quality of our human subsystem, for granted. Should we not have some sort of quality control for our human subsystem, including the electronic or maintenance technicians? A series of diagnostic job task performance tests should be developed to ascertain how effective the maintenance portion of a human subsystem can perform. For example, if a quality control standard of $p = .95$ were required for the signal generator, oscilloscope and VTVM tasks described in the troubleshooting example above the p_T would be increased from .0032 to .663.

NO SUBSTITUTES FOR JOB-TASK PERFORMANCE TESTS

To date no adequate substitutes have been developed for the job-task performance tests. Several researchers have attempted to develop various paper and pencil knowledge tests and troubleshooting tests. Table 2 indicates the correlations that have been reported between job-task performance tests and paper and pencil tests, theory tests and school marks. None of these substitutes are sufficiently valid to be used as substitutes for job-task performance tests.

CURRENT ACTIONS

The use of job-task performance tests is not without problems. Such tests usually are more expensive to administer than paper and pencil tests. For some tasks a one to one, tester-testee ratio is required while for others, one tester can probably observe up to four testees at a time. Another problem associated with job performance tests is that of adequate scoring schemes. The Air Force Human Resources Laboratory currently has a project underway to develop job-task performance tests for each electronic maintenance activity indicated in Table 3 together with appropriate scoring schemes for each activity.

TABLE 2

CORRELATIONS BETWEEN JOB-TASK PERFORMANCE TESTS AND THEORY TESTS, JOB KNOWLEDGE TESTS, AND SCHOOL MARKS

Researchers	*Type of Job Task Performance Test (JTPT)*	*Theory Tests*	*Job Knowledge Tests*	*School Marks*
Anderson (1962)	Test Equipment JTPT			.18-.33
Evans and Smith (1953)	Troubleshooting JTPT	.24 & .36	.12 & .10	.35
Mackie and Others (1953)	Troubleshooting JTPT	.38		.39
Saupe (1955)	Troubleshooting JTPT		.55	.56
Brown and Others (1959)	Troubleshooting JTPT		.40	
	Test Equipment JTPT		.29	
	Alignment JTPT		.28	
	Repair Skills JTPT		.19	
Williams and Whitmore (1957)	Troubleshooting JTPT			
	(Inexperienced Subjects)	.23		
	(Experienced Subjects)	.15		
	Adjustment JTPT			
	(Inexperienced Subjects)	.02		
	(Experienced Subjects)	.21		
	Acquisition Radar JTPT			
	(Inexperienced Subjects)	.03	.36	
	(Experienced Subjects)	.14	.22	
	Target Tracking Radar JTPT			
	(Inexperienced Subjects)	.24	.33	
	(Experienced Subjects)	.20	.38	
	Missile Tracking Radar JTPT			
	(Inexperienced Subjects)	[illegible]	.15	
	(Experienced Subjects)	.19	.32	
	Computer JTPT			
	(Inexperienced Subjects)	.08	.24	
	(Experienced Subjects)	.06	.14	
	Total JTPT			
	(Inexperienced Subjects)	.14		
	(Experienced Subjects)	.20		
Crowder and Others (1954)	Troubleshooting JTPT	.11	.18-.32	

TABLE [illegible]

A CLASSIFICATION OF ELECTRONIC JOB ACTIVITIES

FOR MEASUREMENTS PURPOSES

JOB ACTIVITIES TO BE MEASURED	CLASSIFICATION OF ACTIVITIES
1. Performing equipment checkout procedures 2. Adjusting and aligning 3. Isolating between-stage faults to particular state (or functional unit or physically replaceable unit) 4. Isolating within-stage faults to defective component (tube, solid state device, coil, capacitor, resistor, etc.) 5. Replacing of components	I. SYSTEM OR EQUIPMENT RELATED ACTIVITIES
6. Using oscilloscope (test for each important capability such as measuring voltage, measuring frequency, comparing waveshapes frequency, comparing waveshapes and making high accuracy time base measurements 7. Using electronic voltmeter to measure various ranges of voltages electronic equipment 8. Using ohmmeter to measure direct-current resistance in electronic equipme 9. Using signal generator to inject standard or know signals into equipment for [illegible] purposes 10. Using tube checker to estimate quality of electron tubes 11. Using transistor checker to estimate quality of transistors	II. INFORMATION GATHERING ACTIVITIES ABOUT SYSTEMS
12. Using soldering iron 13. Using soldering gun 14. Using pliers 15. Using diagonal cutters 16. Using wire strippers 17. Using screwdrivers 18. Using machinist's wrenches 19. Using light machinist's hammer	III. EXAMPLES OF HANDTOOL ACTIVITIES

It is hoped that these tests can serve as models for the development of such tests for like activities in any electronic subsystem. We also hope to use these tests as criteria for effective paper and pencil substitutes. In addition, we should develop job-task performance tests for the activity of the mechanical maintenance fields such as the engines and air frames.

CRITERION PROBLEM

In 1946 Jenkins discussed the problem of the criterion in the light of experiences of the Naval Psycholigst in World War II, in an article entitled Validity for What.

> Psychologists in general tended to accept the tacit assumption that criteria were either given of God or just to be found lying about . . . .
> The novice of 1940, searching through many textbooks and much journal literature would have been led to conclude that expediency dictated the choice of criteria and that the convenient availability of a criterion was more important than its adequacy.

In 1964 Wallace presented a paper at the Annual Convention of the American Psychological Association in which he indicated that much of what Jenkins said in 1946 was still true. This paper was published in the American Psychologist (Wallace, 1965) under the title Criteria for What? Wallace stressed that Criteria for What must include understanding.

We should carefully study our current systems effectiveness measures to determine just how much they tell us about the quality and reliability of our human subsystem especially in the maintenance area. Perhaps we have been using only expedient criteria "that happened to be lying about." I am suggesting that the liberal use of job-task performance tests for ascertaining the quality and reliability of human performance would add a necessary dimension to system effectiveness measures. Such tests would also contribute to an understanding of our traditional systems effectiveness measures.

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COMMON CONCERNS COMMON EFFORTS

In a current magazine there is an advertisement by an automotive manufacturing company. It states that it takes a week to make their car and three years to make their mechanic. It goes on to describe how the mechanic is trained and concludes with the words "For once, a man counts as much as the machine." Although this advertisement is concerned with the automotive mechanic and my presentation today is concerned with the aviation mechanic, it is unfortunate that many of us have gone too long equating mechanics with machines.

This symposium is concerned with THE MAN AND THE MAINTENANCE RELIABILITY SYSTEM. The quality assurance of the maintenance reliability system is achieved most efficiently not by the inspection operation, but by getting at causes. The quality assurance of the aviation mechanic's competence is not achieved through training that results in the accumulation of facts but rather in training that develops analytical thinking and highly refined manipulative skills. It is our common concern and common effort in attempting to achieve the latter in the development of the aviation mechanic that binds us together. The schools, industry, and the Federal Aviation Administration are all involved in assisting the aviation mechanic achieve maximum efficiency and effectiveness.

Modern aircraft and their intricate equipment reflect the most advanced technological design and development. Hence the skills and knowledges required of the present-day aviation mechanic have undergone radical, ever-occurring changes. These changes require the aviation mechanic to readjust applicable past learnings and skills to new aircraft designs. Rather than rely on rote learning, he must constantly apply the latest principles of science and aviation mechanics to new aircraft and their continual modifications.

In describing the aviation mechanic we find that he has been the silent partner in the team of men who have helped in the development of the aviation industry. Although he has not been glamorized by stories or films, his dedication toward air safety and his manipulative and technical ability have been some of the major factors in making air transportation more safe, thereby aiding the growth of the aviation industry. "Responsible" is the word that best characterizes the aviation mechanic's attitude toward his occupation. Working under adverse conditions and, at times, with limited resources, the aviation mechanic uses his ingenuity to maintain flight schedules and fill customer requests without sacrificing excellent workmanship standards.

Since the passage of the civil Aeronautics Act, at which time the Civil Aeronautics Administration was formed, a set of guidelines has been developed

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Paper presented to the FAA Symposium THE MAN AND THE MAINTENANCE RELIABILITY SYSTEM at Oklahoma City, December 3-5, 1968, by David Allen, Supervisor, Trade-Technical Teacher Education, University of California at Los Angeles.

whereby comprehensive training could be given in the tasks usually expected of the aviation mechanic. Civil Air Regulations reserved a section which specified standards of training and listed the equipment necessary to provide this training for mechanics. The approach of the schools has been geared primarily to the guidelines developed from these standards, although local conditions have served to accent certain kinds of training and de-emphasize others.

With the advent of jet-propelled aircraft and helicopters and the rapid growth of general aviation, the challenge of training modern aircraft mechanics became awesome. Guidelines alone were not enough. A definite need existed for the establishment of a basic curriculum* that would be sufficiently flexible to remain current with the aviation industry. Both the aviation mechanics schools and the FAA were concerned about determining the demands placed on the mechanic by the aviation industry and establishing the best means of preparing each mechanic to meet these demands.

In response to this concern, in 1965 a nation-wide study of the aviation mechanics occupation was designed: (1) to identify the skills and technical knowledge required by the aviation mechanic upon entering the aviation industry as well as the requirements needed to perform successfully during his employment; (2) to test methods of instruction using student performance goals and to develop a core curriculum utilizing the findings of the testing activity; and (3) to initiate a system to maintain the curriculum current with the requirements of the aviation industry.

Throughout the National Study assistance was given by industry, by the aviation schools, and by the FAA. The FAA in particular supported our efforts by assisting in the identification of industries that could be surveyed; by providing technical assistance when required for our research activities, and by providing an avenue for communications so that our efforts would be of benefit to all concerned with aviation mechanics.

A discussion related to areas in which common efforts can be made for the training and retraining of the aviation mechanic requires a review of the National Study and the experimental activities related to improving instruction. A brief description of the National Study and the experimental activities related to improvement of instruction follows:

THE NATIONAL STUDY

Study Design

A national survey was undertaken to gather data for the accomplishment of three objectives: (1) to investigate the technical knowledge and manipulative skills of the aviation mechanic as required by the aviation industry; (2) to identify a core curriculum for the training of aviation mechanics; and (3) to identify the scope of training offered by industry in order to establish

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*Curriculum as used in this paper is defined in terms of the sum of all the school experience a student has under the guidance of his instructor/s.

relationships between school and industry training. Data collected from the study were separated into four major industrial categories: (1) airline line stations; (2) airline overhaul stations; (3) large general aviation; and (4) small general aviation. Small general aviation, for the purpose of this study, were companies that employed five or fewer aviation mechanics. Only aviation companies employing Federal Aviation Administration certificated airframe and/or powerplant mechanics were included in the study. An aviation density study of the United States resulted in selecting twenty-six states and the District of Columbia for representation in the study.

The study was based on two assumptions: (1) that all manipulative skills require some degree of technical knowledge but not all technical knowledge requires manipulative skill, and (2) that all training in aviation mechanic schools will develop the mechanic's manipulative skills so that he will be able to perform work of return to flight quality. A questionnaire was designed incorporating the basic assumptions with the capability of introducing the collected data directly into the aviation mechanics school c iculum. There were 507 tasks studied, each of which represented a task performed by an aviation mechanic. These tasks were written in behavioral terms.

The questionnaire sought answers to five specific questions: (1) the number of men performing each task; (2) the frequency with which these men performed the task; (3) the level of technical knowledge required to do each task; (4) the conditions under which the return to flight manipulative skills had to be performed; and (5) the depth of training conducted by industry. The identification of levels of technical knowledge was based on a classification of five levels assigned to fit the aviation mechanic occupation. These levels were: (1) knowledge (the ability to recall facts and principles, to locate information, and to follow directions); (2) comprehension (the ability to restate knowledge or to interpret information and drawings needed in performing a job); (3) application (the ability to apply principles or transfer learning to new situations); (4) analysis (the ability to reduce problems to their parts and detect relationships between these parts, such as breaking down a malfunction into its fundamental parts in order to troubleshoot); and (5) synthesis (the ability to assemble the knowledge of principles and procedures needed to complete repairs and to construct new or substitute parts). Manipulative skills were studied in relation to the conditions under which a mechanic performs his duties, such as working under pressure of time and advanced planning before performing a job.

Study Data

A total of 485 companies were contacted and 401 of these companies responded, representing an 82 percent response. The distribution of these 401 companies was 62 airline line stations, 21 airline overhaul stations, 189 large general aviation companies and 129 small general aviation companies. There were 18,080 certificated airframe and/or powerplant mechanics studied and their distribution was 11,428 at airline line stations; 3,830 at airline overhaul stations; 2,463 in large general aviation companies; and 359 in small general aviation companies.

The study results were tabulated through the use of a computer. These tabulated results were presented to a National Advisory Committee. The

National Advisory Committee reviewed the study findings in relation to the number of men performing tasks, the frequency at which these tasks were performed, and the degree of industry training; and made recommendations for a core curriculum.

A review of the data received from the aviation industry during the National Study suggested that certain trends were developing. In addition, some of the findings reinforced some opinions expressed in aviation circles, while other findings revealed that certain opinions could not be substantiated or were no longer applicable to the aviation industry. A compilation of some of the trends follows:

1. There is a common core of tasks performed by all aviation mechanics which require the same technical knowledge levels. There were 73 percent of the tasks performed to identical technical knowledge levels by mechanics in the four industrial categories. This high percentage of the commonality of tasks performed by the aviation mechanics in the four industrial categories strongly supports the premise that aviation mechanics can be trained through a core curriculum and can specialize in the latter part of their training for the industrial category in which they may seek employment.

2. The predominant technical knowledge level at which the aviation mechanic works is the application level or higher. When all the tasks had been analyzed, 86 percent were found to have been rated by mechanics in at least three of the industrial categories as requiring technical knowledge at the application, or a higher, level. Mechanics indicated they can accomplish the remaining 14 percent of the tasks with either the knowledge and/or comprehension level of technical knowledge, which require the ability to follow directions and/or to locate and interpret information. These findings substantiate the need to train aviation mechanics to the application level so that transfer of learning to industry is easily accomplished.

3. The work performed by the aviation mechanic has undergone a number of changes. The airframe mechanic's work has shifted to being primarily responsible for aircraft systems with structural repair playing a secondary function. The powerplant mechanic working on turbine engines works on the various powerplant systems rather than replacing the major engine components or performing top overhauls. In general aviation the use of "throw away units" requires both the airframe and powerplant mechanic to be able to diagnose malfunctions and replace defective units properly. On-the-wing maintenance of turbine engines requires airline line service mechanics to perform some tasks that has been previously accomplished ' overhaul. The overhaul of turbine engines is better classified as repair of components bringing them back up to standards rather than the overhaul procedures followed with reciprocating engines.

4. Many airline overhaul mechanics are specialists in the particular area of work for which they receive extensive training. It was found that the airline overhaul mechanic performs 393 of the 437 tasks. Of these, 364 tasks were performed by less than 5 percent of the

mechanics for each of the tasks. These specialized mechanics received in-depth training for 54 percent of these tasks, basic or general information training for 43 percent, and orientation or no training for the remaining 3 percent.

5. There is an increasing use of turbine engines in general aviation. The percentage of general aviation mechanics performing work on turbine engines has increased. It was noted that training in depth was provided for only ten tasks by small general aviation and seven of these tasks were associated with turbine engines.

6. Fixed pitch wood propellers and ground adjustable propellers no longer appear in airline operation and their number is decreasing in general aviation. In general aviation, work performed on ground adjustable propellers involves minor repairs to the blade and hub. General aviation companies frequently remove and install these propellers but the task is performed at a low frequency.

7. Electricity and electronics are becoming integrated into the airframe and powerplant mechanic's occupation. The mechanics in the airline industry and in large general aviation companies performed all 28 tasks surveyed in the areas of electricity and electronics at a high frequency. Mechanics in small general aviation also performed all tasks at a high frequency, with the exception of checking and troubleshooting solid state switching devices. All indications point to the necessity for schools to increase their emphasis in the instruction of electricity and electronics.

8. The maintenance of flight instruments, automatic flight and approach control systems, and aircraft communications and navigation equipment is extremely specialized work. The airline industry generally provides training in depth for mechanics performing maintenance work on flight instruments, automatic approach control systems and communications, and navigation systems. Mechanics in large general aviation receive training in depth in maintenance of auto pilots and approach control systems and application training in all other related areas. Mechanics in small general aviation receive basic and general information training in the basic flight instruments but generally receive no industry training in any other related areas. Specially certificated mechanics and specialized shops frequently repair these systems.

9. The need for mechanics skilled in woodworking has decreased substantially in the aviation industry. The survey found that the airline industry no longer requires mechanics to be skilled in woodworking. Few highly specialized airline overhaul mechanics perform wood repairs to interior cabinets and paneling. Large general aviation companies assign these tasks to a few mechanics who perform these tasks at a low frequency. Of 2,463 mechanics surveyed in large general aviation, only 174, or 7 percent, indicated that woodworking was part of their assignment. In small general aviation, woodworking continues to be performed by approximately one-third of the mechanics, but the frequency is in the low category. It was found that of the 359 mechanics studied only 126 were involved in woodworking tasks.

The overall percentage of aviation mechanics surveyed in general aviation, large and small, who are responsible for performing woodworking is 10.8 percent. Tasks related to woodworking that were most often performed involved the determination of condition rather than construction or repair.

10. Aviation mechanics must understand the basic operations involved in sheet metal work and must be able to make return to flight repairs to metal structures. Findings reveal that the aviation industry requires more men to possess skill and knowledge in this topic area than in any other task requiring manipulative skill. Representatives of the aviation industry stated that the mechanic must know which types of damage can be tolerated and which need repair. In all cases the work must be of a return-to-flight standard.

11. Aircraft welding is becoming a specialized skill. The introduction of new materials and new welding techniques in aviation require specialized skills for welders. Comments received from general aviation companies indicate that repairs involving welding are done by specialty shops. Specialization in welding is also applicable in the airline industry. In order to become a certificated welder, a mechanic must receive specialized instruction. However, mechanics still must make air worthiness determinations concerning welds.

12. The use of manufacturer's specifications and Federal Air Regulations are an essential part of the aviation mechanics occupation. Mechanics in all four categories indicated that manufacturer's specifications and Federal Air Regulations are used at a high frequency. The number of mechanics who use these publications and manuals is also very high. The airline industry and large general aviation provide basic and general information training in these tasks.

13. To be employable, the mechanic must have a sound command of the English language. The importance of a mechanic's ability to read, write, and speak the English language is in most cases a fundamental requirement for acceptable performance and for advancement in the industry. Accuracy in the use of the English language was emphasized throughout the findings. The schools have a responsibility to ensure that their students are able to meet the standards required in the use of English as required to performance as a mechanic.

14. Ethics and the mechanic's legal responsibilities are an important part of the aviation mechanic's training. This was the only major subject area in the study where the tasks were consistently ranked at the highest level. The survey indicates that the mechanic's integrity, quality of workmanship, and responsibile action in the work environment continues to be an essential part of the occupation.

<u>Industry Training</u>

An examination of industry training indicated that the aviation industry does provide extensive in-service training for the maintenance of occupational currency. Industry training for mechanics is designed to provide currency

when new models of aircraft are introduced and changes occur in existing models. The amount of training is substantial and is generally directed to the basic and general information level. Training in depth is most predominant in the airline overhaul category. Industry training ranged from 81 percent in airline line stations to 85 percent in airline overhaul stations in all tasks. Training in the general aviation industry ranged from 66 percent in small general aviation to 92 percent in large general aviation for all tasks. Table I, displays the percent of tasks studied for which training was given by the aviation industry.

TABLE I Percent of tasks for which training is given by the aviation industry

LEVEL TO WHICH TRAINING IS OFFERED	INDUSTRIAL CATEGORIES OFFERING TRAINING			
	Airline Line	Airline Overhaul	Large General	Small General
No training	19%	1[illegible]%	8%	34%
Orientation or familiarization training	7%	4%	4%	zero
Basic or general information	55%	39%	72%	63%
Training in depth	19%	42%	16%	3%

There were many tasks for which industry offered no training. Training in depth is more prevalent in the airlines than in general aviation.

Result of Study

The FAA through meaningful action has consistently encouraged the efforts of the research staff. They provided the necessary guidance to ensure that the research findings could be effectively channelled into objectives that were in the best interest of the aviation industry and the aviation schools. Following the publication of the research findings the highly qualified Airman Schools Group of FAA review the data and provide the knowledge and experience so necessary to effectively implement the research. FAA has used the basic research data and the National Advisory Committee's recommendations to outline in detail the knowledge and skill required for mechanic certification. The Airframe and Powerplant Mechanics Certification Guide, AC 65-2A*, published in April of 1968, describes the content of the mechanic's test in terms of the achievement level the applicant is expected to reach, although the certification guide does not follow in all respects the avenues suggested in the study. The research data has also been used by FAA as source material for developing recommendations for changes to the curriculum requirements for FAA certificated mechanic schools. Four thousand of the survey reports have been distributed to industry training

*AC 65-2A is available from GPO for 40c per copy.

organizations, educational institutions, aviation maintenance organizations, training advisory groups and other interested persons and organizations where it serves as basic research material to those who have an interest in the utilization and training of aircraft maintenance personnel.

EXPERIMENTATION ACTIVITIES FOR THE IMPROVEMENT OF INSTRUCTION

The implementation of the National Study's findings was the next major step. An experiment was designed to determine whether subject matter in the aviation mechanics curriculum could be learned as well under an instructional system that programs the teacher and his instruction to the student's learning progress, as under the traditional instructional methods now in use in the aviation schools. Specifically the problem was resolved into comparing the relationship between: (1) an instructional system having predetermined student performance goals as compared to current instructional systems that use traditional instructional objectives; (2) an instructional system that provides to the teacher, as he instructs, continual feedback as to how well learning is being achieved, in comparison to traditional instructional systems that have no planned provisions for feedback during teaching; and (3) an instructional system that provides student workbooks utilizing "partial notes" that are coordinated with an instructor's guide, as compared with the traditional instructional systems that make no special provisions for organized note-taking by the student.

Problems that frequently arise in developing instruction are the failure to properly identify the desired learning achievements, and the inability to describe in detail the conditions and limitations of what is to be taught. Instructional objectives, in many cases, do not reflect the purposes of detailed instruction in the classroom and fail to set the parameters for instructional organization, presentation, and evaluation. Teachers need assistance in developing abilities to guide each of their students in meaningful learning activities. Teachers must avoid over-teaching in non-essential instructional areas and under-teaching in essential instructional areas. They must make more effective and meaningful use of all classroom and laboratory instructional time. In addition, they must learn how to appraise continually how well instructional content is being learned at the time teaching is occurring.

Experimental Design

In developing the design for this educational experiment it was assumed that the depth to which the student would learn and his ability to retain this knowledge would be proportional to the extent of his involvement in the instructional process. The first assumption, therefore, was stated as follows: When student performance goals are identified, when levels of instruction have been realistically organized, and when evaluation of student progress has been programmed in the form of frequent feedback between student and teacher, then the amount of learning would increase and retention of knowledge would improve.

The second assumption was based on the belief that an increase in instructional effectiveness could be realized if and when teachers have been properly trained in the presentation of specially designed instructional materials. The design of the experimental program reported here was based on the assumption that the students of teachers who are given specially designed

instructional materials and training in the use of these materials would learn more effectively and achieve greater retention than when the same students were taught by the same instructor using his customary teaching materials and methods.

This study was conducted in both public and private aviation mechanic schools throughout the United States. A total of twelve schools participated in the experiment and a random replications design was used in the inclusion of a bi-variate inversion method for controlling the treatment order. A total of 144 students participated in the initial test and re-test sequence, and the six-month follow-up study included 98 of the original students.

Two concepts that were originally in the National Study were adapted to the curriculum material used in the experiment. These two concepts dealt with levels of instruction which are directly related to the definition of levels that was used in the National Study and student performance goals which were directly related to the task statements in the National Study questionnaire.

The levels of instruction established the standard for learning success measurement described in the student performance goals. Each level of instruction was given an equivalent testing level. In order to determine whether the specific testing levels had been achieved a three level system was used: Level 1: Know basic facts and principles. Be able to find information and follow directions and written instructions. No skill demonstrations were required. Level 2: Know and understand principles, theories and concepts. Be able to find and interpret information and perform basic operations. A high level of skill was not required. Level 3: Know, understand, and apply facts, principles, theories, and concepts. Understand how they relate to the total operation and maintenance of aircraft. Be able to make independent and accurate airworthiness judgments. Perform all operations to a return-to-service standard. A fairly high skill level was required.

Student performance goals describe the sought-for response or behavior of the student at the conclusion of a segment of instruction; they provide a way for the instructor to recognize the point at which predetermined observable changes have occurred in the student's performance. These goals are established by those individuals who are responsible for curriculum design, and may be expressed in terms of how a student performs.

Student performance goals are statements in a curriculum that are characterized by three component parts: (1) what the student will be able to do; (2) how he is going to do it; and (3) how well he must do it to be considered successful.

The experimental subject in the study was Aircraft Hydraulics. Instructional materials were provided and the teachers trained in the use of the materials. Seven different control subjects were used by the schools in the experiment. The control subjects were selected by the teachers. Both the control subject and the experimental subject were taught by the same teacher to the same students in each of the sub-populations.

The results of the experiment were analyzed through controlled testing following the completion of the sixty clock hour course in Aircraft Hydraulics

and a sixty clock hour course in the control subject. The retention effect was studied following a ninety day re-test in the same subjects. This was further substantiated by a six-month follow-up test. The examinations for the experiment were developed and administered by the FAA. The same examinations were used for initial testing and re-testing, the only difference being that the questions were rearranged. The six-month follow-up used the FAA official certification tests results for the students involved in study and who had taken the test for their mechanic's certification.

Experimentation Findings

The test of significance of the treatment indicated convincingly that in almost every case the students performed better in Aircraft Hydraulics than in any of the control subjects, despite a comparable difficulty index for the several examinations. It was not the intent of the experiment to measure in isolation each technique and concept used in the innovated curriculum materials. This is normally the approach in educational research. The learning process, however, is more complex, and each part is supportive or contributive to the whole concept. The study emphasized the basic teaching tools that can be made available to all teachers, irrespective of the sophistication of the technical equipment available or the economic level of the school. Elements tested in the experimental approach included: (1) Designing the curriculum to include levels of instruction. (2) Identifying desired outcomes through student performance goals. (3) Developing coordinated instructor's guide, student workbooks, and training aids. (4) Training teachers to use the coordinated instructional materials and to apply the concepts of student performance goals and feedback in their teaching. (5) Using feedback to constantly ascertain the amount of learning that is taking place. (6) Testing for student performance goal achievement.

It was not the purpose of this experiment to evaluate the influence of any single one of the above elements as an entity in measuring the effectiveness of the instruction. Each, however, contributed to an improved learning environment which can be controlled by the individual teacher if he has been given the proper knowledge for implementation. Evaluation of the experimental data suggested the following deductions; however, caution must be exercised in making definitive conclusions in light of the limited scope of this study:

1. When student performance goals are clearly defined and are known by both the teacher and the student, the quality and quantity of the learning will improve.

2. When the levels of instruction are known and adhered to, more efficient instructional planning and therefore more efficient classroom instruction will take place.

3. When feedback checks for learning are prepared in detail prior to each lesson and the teacher utilizes feedback during instruction, student learning progress increases.

4. When improved instructional planning and teaching methods are used, instructional time may decrease without a loss in learning.

5. When teachers are trained to use instructional materials and utilize concepts concerned with student performance goals and continuous feedback, students achieve greater depth of learning and retention.

Some indications suggest that the number of instructional hours devoted to the subject is not the only important criterion for increased learning. In this experiment it was noted that regardless of the number of hours devoted to teaching the control subjects, students failed to achieve the same level of excellence on the examinations as in the experimental subject. In fact, performance in some areas declined with increased instruction, suggesting the possibility of retroactive inhibition. The experiment results suggest that the use of levels of instruction, student performance goals, and feedback in instructor preparation, curriculum organization, and instructional planning can influence learning to a greater extent than usually is anticipated the amount of time necessary to teach a particular subject. It must further be emphasized that without proper teacher preparation and acceptance of the experimental concepts, regardless of the amount of previous teaching experience, the success of the instruction and of learning achievement will be limited.

It would appear, therefore, that students will enter the aviation mechanic occupation with a broader base of knowledge from which the retention effect would operate in proportion to the influence of time and use, when the instruction methods tested in this experiment are implemented. Thus the experiment provides a suggested instructional system that can assist aviation mechanics both in school and working in industry to better achieve instructional objectives.

DISCUSSION

There are a number of implications derived from our research activities of which both the schools and industry should be cognizant. Some of these implications relate to ways for providing more effective instruction. The other implications are related to the inter-relationships between the schools and industry.

Task Inventory

Record systems developed by industry for keeping track of materials production, etc. have been developed to a high degree of efficiency. Generally lacking are analyses of the tasks that are being performed that require training so that these tasks can be performed more efficiently. This does not mean that industry is unaware of the tasks aviation mechanics perform, but rather that a system for early identification of changing training requirements is not apparent. There needs to be a system so that a continuous task inventory identifying training needs can be maintained. Task inventories finding should be made known to the FAA so that on-going changes in the aviation industry can be communicated to the aircraft mechanics schools. The communication to the schools should be in terms that will assist the schools in integrating these task requirements into their curricula. The task inventory can be conducted on a select sample basis so that expensive surveys need not be conducted in order to obtain necessary data. The task inventory should use the concepts of levels and frequency as well as the number of mechanics and the frequency at which they perform tasks in an attempt to identify training requirements for the various tasks the air mechanic performs.

Establishment of Student Performance Goals

A common occurrence in industry when providing training for new equipment, is to design the training program around units of time. Prior to the arrival of the new equipment, instructors from a particular company are sent to a factory school to learn as much as they can about the new equipment. Unfortunately, the factory does not have enough experience with the new equipment to identify areas in which training is needed as opposed to areas that are just nice to know. The instructors upon returning to their company select from an accumulation of slides, transparencies and manuals, items of general information they believe those in their classes should learn. Many hours may be spent on non-essentials and at times the necessary items for servicing the aircraft are discussed in a short period of time and not emphasized, so that when the mechanic begins to work on the aircraft he has to dig for himself and learn through trial and error. After a company uses the aircraft for a period of time, areas that need additional training are identified and these training programs are designed to the degree that instruction is effective and efficient; and, in addition, is accomplished in a fraction of the time required when the equipment was first introduced. In the schools a list of activities are developed and the student goes through these activities, and in many cases, limited by time, goes through a program not always accomplishing the task to the degree necessary for becoming an aircraft mechanic. It is imperative that instructors in industry when receiving their initial training in a factory school on new equipment begin to determine the performance goals mechanics need to have in working on the aircraft and gather the information necessary to teach the achievement of the performance goal. It does the mechanic no good, other than general enlightenment, to know that the wing span of the airplane is twice the distance of the Wright Brothers original flight. It is more important that the mechanic know how to fill properly a hydraulic tank that may have peculiarities unique to a particular aircraft. For instructors in aircraft mechanic schools it is necessary that they, too, identify the performance goals for the various learning activities so that they can measure how well a student is achieving the instructional goal in order to eliminate under-teaching or over-teaching of material that is non-essential.

Adjustment of Instruction to the Level of a Group

It is well established that each of us learns at our own rate and that instruction, to be most effective, should be designed to meet each of our individual rates of learning. Because we teach to groups it can become difficult to meet the individual learning rates of our individual students. Automated feedback devices, teaching machines and multi-media instructional systems have been designed to assist in providing for individual instruction. In many cases these units can not be utilized for instructional needs that may be of short duration or that require immediate instruction, and there is not enough time for the development of the instructional media that compliment these systems.

There are those who visualize the elements of learning and creative activities as units of production. Trend or progress charts are kept to record output of these types of activities. Individuals who are learning or who are performing activities requiring creative thinking should not be

compared to the production line where an "X" number of tin cans are produced per hour. This type of management of instruction or creative thinking jeopardizes the accomplishment of the objectives originally established.

On the job training in industry does provide an opportunity for the instructor to adjust his instruction to the different mechanics he is training. However, classroom instruction in both industry and schools should attempt to adjust the level of instruction to the experiences, abilities and needs of those enrolled. An instructor might describe the testing of an armature stating that: "In testing an armature the eddy currents can not be neglected. Unforeseen temperature transients would cause the device to become non-operative during preliminary tests." To a particular group of students, this statement would be quite understandable. On the other hand, he could make the same statement to another group stating that: "In testing an armature, if you get it too hot it will melt." Thus, it is not only important to consider grouping students by levels but also it is important to present the instruction appropriate to the level of the students.

Selection and Training of Instructors

Individuals selected as instructors should have three basic qualities. They should have the necessary technical skills and knowledge, they should have the ability to communicate their skills and knowledge to those they are teaching, and they should have a desire to assist others to learn. The majority of instructors are generally strong in technical content, and some can rattle off facts as quickly as a calculator. Unfortunately, many are not aware of the basic elements in teaching, nor do they plan their instruction for maximum effectiveness, nor do they provide for adapting their instruction to the various levels they are instructing. In many industries top management must develop an accepted relationship between those responsible for training and line supervision so that conflicts do not arise and maximum impact of the instruction can be achieved. Instructors need assistance in identification of what is to be taught and the ways that will best accomplish desired results. A system for instruction that identifies the skills to be attained, the technical knowledge to be achieved, and encompasses closely coordinated tests for evaluative purposes, criteria for grading, and an effective record system are needed in both schools and industry if credence can be placed on how well each student has learned.

Dissemination of Technical Information

Aviation mechanic schools to be effective need both current aviation equipment suitable for instruction and technical information. It is difficult to obtain both of these elements inasmuch as equipment is expensive or not obtainable for instructional purposes and technical information is generally tied to specific components or equipment. There is extreme need for a national aviation mechanics educational materials resource center. This center should be located where information from the aviation industry is collected. An example of such a center is the Maintenance Analysis Center located at the FAA aeronautical facility in Oklahoma City which is the focal point of the agency for the collection, analysis, and distribution of aircraft maintenance reliability information. Information now coming to the center, although

of great value for the intended purpose, generally has little value to the aviation schools. What is needed is an individual or individuals competent in curriculum development and the technical aspects of aviation. These individuals would need to sift through the incoming technical information and gather together the technical information applicable to the instructional needs of the aviation schools. The information could be written up as informational bulletins and be supplied on any kind of reproduction system to the aviation schools. A quarterly advisory circular could advise the schools of the technical bulletins marked for training only available. This system could provide appropriate current technical information to the schools thus eliminating the delay time in getting current technical information into the instructional program of the schools. It is strongly recommended that an instructional materials reservoir and dissemination center similar to the Maintenance Analysis Center be established to take advantage of the present reservoir of information that is already available and to encourage and expedite future development for interchange among industry, the schools and FAA.

This resource center could also contain a library of other instructional materials that could be loaned to certificated aviation mechanic schools. This type of activity would provide service to the aviation industry by promoting quality aviation mechanics education throughout the nation.

The Role of Industry and the Schools

The certified aviation mechanic schools provide one of the best recruitment sources for the aviation industry. Although the aviation industry utilizes this recruitment source, it is lax in cultivating this source. It is a situation similar to a major league baseball team needing a source for new ball players but reluctant to support any type of farm team system. Industry must establish a closer partnership with the schools. Sitting on an advisory committee that may meet a few times a year or supplying expendable materials to the school is not enough. Industry must take a more active part in assisting the schools if it is to be the recipient of more adequately trained aviation mechanics.

Industry must realize that the aviation mechanic schools cannot train their students to the nth degree in all tasks. The schools can provide training in the basic skills and technical knowledge necessary for entrance into employment, and with a minimum of additional training in industry, the new employee can advance more rapidly and become economically productive in a short period of time.

When aircraft and aircraft equipment become similar for many companies then the schools can provide a broader base of training. As long as companies have different types of equipment and maintenance procedures the schools must provide the basic skills that permit refinements through on-the-job training after employment. Industry must provide the training on their equipment and in the specialty areas. The schools provide the foundation for the skilled mechanic and can also provide various types of upgrading programs in which the employed aviation mechanic could enroll. Some of the schemes for tuition assistance being provided for engineers could be adapted for the aviation mechanic.

Industries should provide opportunity for employment on a scheduled basis for the instructors from the aviation mechanic schools so that they can maintain their occupational competence. The exchange of instructors and technical personnel between industry and the schools would be beneficial to both and would provide the base from which aviation mechanic instruction in the schools would become more effective.

There needs to be a coalition established between industry and the schools. The major objective of the coalition should be directed toward the increased technical competence, in both skills and knowledge of the aviation mechanic in the nation. The time is long overdue for this type of concentrated effort. Unlike persons in some occupations in which relatively little change occurs, the aviation mechanic must continually study to keep abreast of rapid technological changes. This need for continual training challenges the schools and industry to provide appropriate educational programs. Through cooperative effort, the challenge can be shared by both.

Will Rogers stated "Don't let yesterday use up too much of today." We must not spend our time "hangar flying" expounding on our past accomplishments nor must we build a "Wall of China" around ourselves in the belief that we know all the answers and that our ways are best. We must develop a common effort for the advancement of the aviation industry for today and tomorrow.

The Responsibilities of the Certificated Mechanic School

in the

Maintenance Reliability System

by

John T. Griffin

Oklahoma City - December 4, 1968

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Before delving into the functions and responsibilities of the certificated technical schools a brief historical synopsis may prove helpful. About 40 years ago the Government first took cognizance of aircraft maintenance when it created the Aeronautics Branch of the Department of Commerce. This was superceded in 1934 by the Bureau of Air Commerce, which published standards and regulations governing aircraft maintenance.

It then published regulations governing the certification of mechanic schools, and these ultimately became known as Part 53 of the Civil Air Regulations.

Part 53 prescribed minimum requirements for faculties, facilities, curriculum and achievement standards. May I quote the following extract from the certificate: "Upon finding that its organization complies in all respects with the requirements of the regulations relating to the establishment of an air agency it is empowered to operate a mechanic school". Part 53 was engrossed prior to the advent of the DC3, when nearly all aircraft were of steel, wood and fabric construction. During the past 35 years there has been no significant change in the requirements for certification despite the fact that the construction and complexity of aircraft have changed radically.

Immediately following World War II came the revolution which introduced systems technology - such as cabin pressurization, heating and air conditioning, thermal deicing, multi-voltage electric systems, electronics, etc. These were quickly followed by the introduction of the turbo-prop and half a decade later by the jet age. These rapid changes created severe problems for the schools.

By the early 60's there were 60 or so certificated schools, and slightly over 70 in 1966. There are now 104 - undoubtedly due to a sudden elated awareness by educators that we have an aviation industry in this country.

I think I should here briefly outline the various administrative frameworks within which the certificated schools operate. As of 1967, 17 were privately operated and 58 were located in local tax-supported institutions. The private schools, of course, must rely solely upon tuitions for survival. However, they have the advantage of being free to function independently of regulations or customs related to other courses of study conducted within the same institution. Of the tax-supported group many are located within colleges and universities. Many others are located in the state junior college networks. Still others are located in the vocational high school systems. It is noteworthy that the 17 tuition-supported schools are the ones that annually contribute the only numberically significant group

who actually secure A&P certificates and accept journeyman employment in the industry. This group of schools produces more than 70% of the A&P input. I may add that these schools do not cost the Federal taxpayer a single penny.

As I mentioned, there has been a vast increase in the number of certificated schools during the past several months. All of which have been certificated under the 1936 standards. However, let's look at the record to see how the system has functioned, and if it has served the needs of the industry. In other words, are the schools any good or are they not?

Visits to any small cross-section of the schools high-lights the fact that there must be a vast difference in interpretation of the Federal Regulations; by the schools, by FAA Inspectors, or both. Variations in the competence of individual schools are to be expected, but the purpose of regulation is to provide enforceable minimum standards determined by competent authority to be adequate to produce an acceptable graduate. Many of us seriously question the usefulness of regulations because of these variations in interpretation and enforcement. Nevertheless, many schools have, and will continue, - to voluntarily do what is necessary to satisfy the employers. On the other hand, I am sure you have heard it said many times that the A&P schools are "no good". Such remarks have undoubtedly been prompted by an unhappy experience with the product of some sub-standard school. But as a result, we all get tarred with the same brush, because we all hold the same certificate of competence. I think that if certification is to continue it is imperative that we operate under constantly updated regulations, rigidly interpreted, and enforced. This corrective action should be taken immediately because of the large increase in applications for school certificates.

While these remarks may appear critical of FAA, I want to here acknowledge that for many years there has been a small group of dedicated and competent men administering the maintenance and schools branches of Flight Standards Service. This group has worked long and hard to effect the necessary revisions, but appear to have been frustrated by administrative red tape, and lackadaisical enforcement by field personnel with whom they have no direct contact.

While I am admitting that the schools are far from perfect, let's also look at the other side of the coin. I rather recently heard some criticisms levelled at the schools, which in my opinion, are unjustified, and which seem to stem from a lack of understanding of the mission and responsibility of an A&P school. For example, I heard an airline maintenance supervisor complain that a recently hired A&P graduate was not competent to weld stainless alloys although he stated that he had been trained in welding. To complaints such as these I can reply only that the job did not require an A&P, A&P training does not produce a welding specialist, and this seems to have been a case of the right man in the wrong slot. I think it is our joint responsibility to clear up misunderstandings such as this.

I don't doubt that my remarks up to this point may make it appear that we conduct our manpower and placement activities in an atmosphere of chaos and misunderstanding. This is not so, although much improvement is needed. Our system, despite its imperfections, has performed well in meeting the A&P manpower requirements of the industry. Our British friends handle the problem in quite a different fashion, and find that they also have problems. I believe they are currently studying us and that some of their prominent men are urging conversion to our system - the system that has produced a major share of our industry require-

ments for the past 35 years. The general acceptability of the men produced under this system is attested to by the intensity of industry recruitment in most of our schools. I think also it is self-evident that we have saved the industry millions of dollars in technical manpower selection and training costs. In support of this statement I note in the current issue of American Airlines' employee publication, "Astrojet News," the following questions and answer: Q. Is it possible to set up an apprentice program for aircraft maintenance? A. (From maintenance and engineering) "Yes, it is possible to set up an apprentice program. However, the overriding consideration is that it would not presently be a sound decision for American to undertake the cost of an apprentice program in view of the availability of trained personnel from the military and the many vocational and technical schools". However, it then adds the following: "If, however, at a future date it should be found that these sources are unable to produce a sufficient volume of personnel, the establishment of an apprentice program might well be not only a possibility but a necessity."

So far I have been talking about the past. Now let's look at where we are and where we think we should be going on manpower requirements for the future. One of the major factors always has been, and I'm sure will continue to be, supply and demand, and the achievement of a balance between the two. I think experience has proved the ability of an alert school system to take whatever action is necessary to meet future manpower reaquirements. However, and this may surprise you, in our diligence we must be equally careful to make sure that we do not, except temporarily, produce a large surplus, for reasons I will get to later.

From remarks which I have heard over a long period, I think that many people harbor some vague and incorrect ideas as to just what a technical school is. It seems that some feel that it is a group of altruistic individuals totally dedicated to the ideal of educating our young men, giving little or no thought to anything else. While we do have many such dedicated people may I assure you that someone has to devote considerable time and study to matters not directly concerned with instruction. A technical school is a business, in some cases rather large, and is subject to all the problems, pressures and economic factors faced by any other business. Furthermore, in the aviation field some of the problems are much more severe and expensive than in other fields. Speaking of schools in general, their establishment or expansion may require only heated and lighted classroom space, plus furniture. In aviation technical schools, the addition of each square foot of classroom space requires the addition of 5 to 10 square feet of supporting laboratory and shop space, which space must then be equipped with expensive, and many times very scarce, hardware. We need more help from the industry on this problem. The only support for this kind of facility is students - warm bodies in the chairs. While it is true that many of our schools are either tax-supported or aided by endowments, all school administrators must periodically take a close look at the effectiveness of these programs. And you can be sure that there is always some other group in the institution which thinks it could use the space and funds to better advantage. But, in the case of the tuition-supported schools, where the majority of our A&P's come from, students in the chairs are a stark, immediate and continuous necessity. These schools must break even or close. And additionally, they must have operating surplusses if they are to improve or expand.

What produces these students, who are so highly essential? Each institution has developed its own ideas and methods for student procurement. These methods

range from national advertising, through local advertising, direct mail, radio, and the employment of school contact representatives. But whichever it may be, success or failure of the program at any given time is highly dependent upon the current image of the aviation industry in the mind of the prospect. He usually makes it his business to find out if it is an industry in which he is likely to be assured of immediate employment if he spends his money and time on a technical education. Additional important factors in student recruitment are referrals and recommendations, by satisfied students and graduates. And the one most important and sensitive factor governing this "current image" and the volume of referrals is the present industry demand for A&P's.

During the past 15 years I estimate that the industry has gone through 4 major cycles in demand. These cycles appear to have been caused by, or timed with, major changes in the mix or character of the aircraft fleet; or the trend in industry profits. If industry profits feel the squeeze, so do maintenance department manning tables. Hard experience has taught us that when there is a substantial number of graduates unable to find early placement in the industry, then the word spreads real fast. The situation is then quickly reflected in new enrollments, as well as in a sharp increase in drop-outs. Many of these students have to work pretty hard to earn their education and if they sense a fading rainbow at the end, they quit and go elsewhere. I think I sense indicators that the storm flags may now be starting to fly again. Industry profits are feeling the squeeze, and already some scheduled industry recruiting visits are being deferred of cancelled. Let's hope this is very temporary.

When industry personnel offices hit the panic button again after one of these down-cycles they naturally encounter reduced output from the schools, and again arrive at the conclusion that the school system is unable to cope with their manpower demands. But we always manage to catch up. In our own behalf, I will state that the industry forecasts of manpower requirements have been pretty hard to live by. About 3 years ago the industry was polled for a 3-year forecast of its requirements. In hindsight, it now seems that during this period the number of A&P's employed must have been nearly double the estimate. For example, one employer estimated its requirements at 360 per year. Eighteen months later it stated that they needed 1000 men during the ensuing 12 months. Revised industry forecasts were then accompanied by some statements strongly urging the schools to sharply increase their capacities, or the industry would have to undertake its own training programs. Several of the schools responded magnificently and spent hundreds of thousands of dollars in creating and equipping expanded facilities. A survey of 30 schools conducted last spring for the personnel office of the Air Transport Association showed that the number of full-time day students enrolled in those 30 schools at the end of 1967 was 5,002, and these same schools reported that upon completion of their expansion programs they would have room for more than 9,000 students, an increase of about 80%. I consider this a pretty good response to the needs of industry. Remember, these statistics covered only 30 schools. Today there are 104 schools, many so new that we do not yet have information on their capacities. But if we assume that the capacity of the other 80 schools will equal the capacity of the 30 mentioned, then we will shortly have seats for over 18,000 students.

In addressing a group of our schools in Boston last April, Joseph L. O'Brien, Vice President-Personnel of the Air Transport Association quoting from a study by Arizona State University, funded by the Economic Development Adminis-

tration, said that the air carrier industry could be expected to employ 95,000 new mechanics in the 15 years ending in 1980, or an average of 6,300 per year. This study further indicated, for the same 15-year period, a total industry-wide requirement of approximately 138,000, of which only one-third need be A&P's. An average annual requirement of about 3,600. These statistics mean to me that the presently certificated schools only are capable of meeting the projected industry requirements, as forecast by Arizona State.

I think it is rather appalling to note how A.S.U. proposes to correct the manpower problems in the aviation industry, which they profess to have discovered through their government-financed study. I urge you to request a copy of U.S. Dept. of Commerce News, file No. EDA68-608, dated September 15, 1968. It fills in the details of a national aviation training center to be operated by Arizona State, near Phoenix, with a capacity of 2,000 students. Based on limited information, I can be sure of only one thing - it will cost you and me a lot of money.

Further with respect to manpower, may I quote from a report by Jack Hunt, Director of U.S. Employment service dated last June. This report concerned a joint survey by the Bureaus of Employment Security and Labor Statistics. Hunt said, "the first phase of this study has been completed and shows that by and large despite the growth of the past few years, airline operations as of 1967 were generally not impeded by manpower shortages." I can add that we now know that they are not being impeded by shortages in 1968 either.

Having reasonably estimated that the existing schools will provide seats for approximately 18,000 students, let's take a look at another aspect of recruitment and see what must be done if we are to get the quality as well as quantity. I was recently asked by the manager of one industry personnel department what the schools intended to do about trying to cope with the overwhelming demand which he already felt was upon us, and asked why I didn't again double the size of my own school. My answer was very simple. First, I told him I did not believe that the current rate of demand would be sustained; and secondly, if I doubled the size of my school I had not the slightest idea where the students would come from. (Incidentally, as side information my school has a current enrollment of 550 full-time day A&P students) My school is located in the midst of one of the most thickly populated areas in the United States; but at this time it would make no sense whatsoever to increase its size! Despite our intense and efficient recruitment methods, we just don't have that many applicants.

I am also in an area where some of the finest public schools in the country are producing the high-school graduates who become our prospects. I must be a little dense, or getting old, but I admit I am puzzled as to just which method of recruiting will coax 2,000 qualified young men, and note that I use the work qualified, to attend a national training institute in the Arizona desert, a state with relatively low aviation activity.

Recognizing that employers will demand more highly trained graduates, the quality of student input is a matter of major concern to the better schools. You have probably heard it said with regard to computers, "garbage in - garbage out". Let me assure you that this applies just as much to technical schools

as it does to computers. In Boston last April, Emerson Roney of American Airlines talking to a group of our school administrators made this statement, "I bring these matters before this group today because I believe that both the educators and the industry must hone t ir selection processes to a fine edge." I couldn't agree with him more, and quite a few of us have been working for years trying to recruit enough students so that the honing process could be applied. There is still quite a gap to be filled in this area. However, when I use the word "garbage" may I explain that I do so relatively and not literally. We do have a large number of very high grade students, but not nearly enough.

As I said earlier, a technical school is a business, and if these schools are to survive there must be students in most of the seats. Not too many years ago one of the principal requirements for admission to college was having the money. Later, as parents began to realize that higher education gave their offspring a better chance for success, as they became more affluent, and as our status-conscious society tended to make the lack of a college degree a stigma, then the colleges gradually became flooded with applications. And it was not until then that they started to hone their selection processes. Or, stated in another way, the selectivity of a college is in direct proportion to the ratio of the number of applicants to the number of seats. It would horrify some educators to admit this, but you and I know its true. It is likewise true of our technical schools.

Fortunately, in my own case during the past 5 years we have been able to become more selective. At present we are turning down about one out of each 5 applic ts who meet our criteria for admission. We have slowly but constantly upgraded our requirements, thus permitting us to gradually install a much more demanding curriculum. Some other schools are doing the same thing, but many still must accept nearly anyone.

How are we, and by we I mean the schools and industry, going to really rn the corner on this "fine honing?" The only possible event that will permit it is a vast increase in the number of applicants. It is a vexing problem to which I have given considerable thought. Educational statistics covering the 6 New England states, (I do not have the national statistics), for the past 7 years show that the maximum percentage of male high school graduates going on t technical education, in all categories, has not exceeded 10%. That percentage is slowly decreasing, and in 1967 it was only slightly over 8%. Some of the reasons for this decrease are readily identifiable; first and foremost is parental pressure for a college education. A recent survey of guidance directors conducted by Boston College showed that 98% of them agree that parents push large numbers of boys into college who never should be there. And, of course, a high percentage of these become dropouts. Next in importance, is the constant increase in the number of tax-supported regional and community junior colleges; and thirdly, selective service - the war.

Since the post-world war II baby bulge public school enrollments have constantly increased and, consequently each year the high school output has climbed. Now, although the population explosion will continue, we appear to have reached a plateau in high school output which will continue for the next few years. Therefore, it becomes obvious that all schools below college level, offering post-high school education, must compete for their students within t t 8% of the total high school output. Recruiting

efforts within this group are becoming more intense and diversified as completely new technologies enter the market - computer technology for example. Obviously, we in aviation really have our work cut out for us if we hope to further sharpen our honing processes. You can't hone much unless you have excess material. May I close this subject with the suggestion that the problem requires the closest study, cooperation and mutual assistance between the schools, FAA, and all segments of the industry.

Now, assuming that we have all the desired students, what are we going to do with them in the future? As I said, the curriculum requirements have not changed in over 30 years, but I am happy to say that it is not true that nothing has been done about it. The group of men in the airman schools branch to whom I previously referred, have been aware of the deficiencies of the status quo and through their efforts a financial grant was made available to UCLA to conduct an in-depth study of the aircraft mechanic occupation. This study was to determine which subjects a mechanic should know, the skill levels which should be required in each category, and the best ways in which to impart this education and training. This project has now been in progress for several years, ably led by Dr. Allen. They have come up with very significant findings and recommendations. Some of our schools have been privileged to participate to some extent in this project and have found it most enlightening. Dr. Allen's studies have resulted in the formulation of a proposed modern curriculum. This has been coordinated with industry and submitted for comment to the Aviation Technician Education Council, our school organization. After many months of meetings, consultations and revisions we finally achieved almost unanimous ratification in April 1967. Now, more than one and one-half years later we are still impatiently awaiting action from FAA headquarters.

Most of the school administrators feel that the new curriculum will be a giant step forward in producing a more effective graduate. Several schools, including mine, took immediate action to revise and rewrite instructional material, and to make the expenditures necessary to equip for the new curriculum. But, the wheels of the Gods grind slowly!

I sincerely hope that this effort on my part to tell it the way it is will start the ball rolling toward closer co-operation between the schools, FAA and all segments of the industry. We should initiate immediate joint action to give the recruitment system a badly needed shot in the arm, and I have some suggestions. First, the "grease monkey" image still persists in the minds of many youngsters, and in the minds of nearly all their parents. We must glamourize the aircraft mechanic occupation through a joint public relations program which will cause a constantly increasing number of better qualified young men to investigate this field. The term "mechanic" must be dropped and superceded by "technician," a similar change was made in many other industries a long time ago.

The schools henceforth should be certificated as "Aviation Technician Schools", and the student objective should be the "FAA Airframe & Powerplant Technician Certificate". I have been personally urging FAA to make these changes for more than 10 years, and I now sincerely hope that they will become effective concurrently with the revision of Part 147, the new curriculum. Immediately following these changes should be an intensive FAA - industry educational pitch, on a nationwide basis, directed at high school counsellors, keeping them thoroughly informed of the outstanding opportunities inherent in this occupation. May I repeat, these steps are absolutely essential if we are to attract a greater number of scho-

iastically superior applicants.

I do not wish to overemphasize the recruitment problem, or convey the idea that our problems are over if that one is solved. We realize that we must also emphasize and constantly concern ourselves with the adequacy of instruction. This means maintaining contact with industry to constantly determine the general acceptability of recent graduates, and to keep updated on proposed changes and methods which may require curriculum revisions. And by the way, in some cases these curriculum revisions result in increased costs and tuition charges. We also have the constant problem of procuring and retaining a competent faculty, one comprised of men who have had actual experience on the industry firing line. Then there is the problem of trying to keep the faculty current with the latest changes in equipment and practices. Here again, I strongly urge the creation of a joint school-airline committee to try to work out an industry-wide plan or policy under which our faculty members could work with selected industry maintenance crews or schools, for periods of one to two weeks at a time, at the expense of the school, of course. I feel confident that joint committees could work out many mutually advantageous innovations in this area.

The objective of this paper, assigned to me by FAA, was to define the functions and responsibilities of A&P Schools in the maintenance reliability system. I suspect that up to this point I have not done so. A couple of weeks ago as I sat scribbling my outline, and pondering the sequence in which my points should be presented, I became convinced that it would be futile to state the idealistic factors only, without first treating with the factors which up to now have made it impossible to fully achieve the ideals. I think it is of the utmost importance that all of us thoroughly understand these problems and work jointly toward their elimination. I believe that a majority of the certificated schools have a sound perspective of their functions and responsibilities, and do their best to carry them out. To aid in this, the schools have their own national organization, "The Aviation Technician Education Council", which numbers more than 60 certificated schools in its membership. The purpose of this council is to provide a medium of communication through which ideas and information may be interchanged for the purpose of producing mutual self-improvement.

I have discussed the substance of the title of this paper with several school administrators and will now try to set forth what we collectively feel to be our functions and responsibilities. First, the school must sell aviation to a prospect who is at least a high school graduate, not interested in college at that time, has some knowledge of science, and thinks he would like to work with his hands. He should also be of good health and character. The school must then carefully screen all available applicants for the purpose of selecting only those who appear qualified, and capable of completing the required training. Those selected must then be taught the basic aerodynamics, physics, mathematics, etc., to equip them to absorb the knowledge necessary to a thorough understanding of the theory and principles of the various powerplants and their components, airframes and their components and systems, electricity and basic electronics.

In addition, the student must be required to work with all the necessary hardware, equipment, training aids, etc., to enable him to put his theoretical training into practice while developing the necessary manipulative skills to qualify him for initial employment. He must be taught drafting and blueprint reading to a level where he can interpret maintenance manuals, Federal Air Regulations, and

engineering specifications. He must be taught the care and use of fine tools, that he must always use the right tool for the job, that he must keep himself and his work area clean and orderly. He must be taught to determine whether a repair is right or wrong, and that there is no such category as "good enough". He must be made to thoroughly understand that the Aviation Maintenance Technician is the absolute benchmark of air safety, and that he must forever be aware of his moral and legal responsibilities. He must be taught to work safely, and always be conscious of the safety of others with whom, and for whom, he is working. We must also indoctrinate him with the idea that the completion of A&P School is only the first step in his aviation education, that he must constantly seek opportunities to add to his knowledge and education and to make himself more valuable to his employer. In summary, it is the responsibility of the school to feed into industry a continuous supply of men possessing the best general aviation and technical education consistent with their own inherent capabilities, and to eliminate those who cannot make the grade. The man they pass to industry is not a specialist but he should have a sound basic knowledge and understanding of the theory and construction of the entire aircraft, its powerplants, its systems, their individual operation and functions, and their basic inter-relationship to each other and to the entire aircraft. When released to industry he also possesses a Federal A&P Certificate which firmly establishes a yardstick of his knowledge. There could be added to these a long list of supplementary concepts which naturally accrue to the student who receives his education through a soundly-structured technical curriculum with peers having objectives identical to his. Thank you.

TRAINING IN AIRCRAFT MAINTENANCE ENGINEERING
A BRITISH APPROACH

Introduction.

In discussing a British Approach to Training in Aircraft Maintenance Engineering before an experienced audience such as yourselves, I will concentrate on two major differences between the situations which exist in the United States and the United Kingdom. These are, firstly the environment in which we are training and, secondly our very high reliance on internally organised apprenticeship schemes in which boys start with the major British Airlines at the age of 16.

The Environment.

Let us consider now the environment in which we operate. We must always remember that we are using a man/machine combination; either component of this combination may be incompatible with the other. In dealing with the training of the man we must, therefore, take due account of the changing nature of the machine. In addition, the effect of the external constraints which surround the actual task to be performed by the man/machine unit must be understood. Such constraints may be of a physical and tangible nature, or they may be regulatory controls.

The current state-of-the-art in the major long-haul airlines of the World is dictated by the technological achievements of the B.707/DC-8/VC.10. type of aircraft. We recognize that we have a well established baseline of knowledge and skills which is appropriate to these fleets. Introduction of the wide-fuselage high capacity equipment such as the B.747/DC-10/L.1011 will certainly be an evolutionary process from a technician's point of view; indeed the BAC/Sud Concorde, although it will quicken the pace, will not be a revolutionary step.

However, the ever-increasing emphasis on cost reduction and high utilisation with our next generation of aircraft brings one particular area of the airline maintenance organisation very clearly into focus - that of the associated ground equipment. In fact, if I may digress from the main theme, we have found ourselves being drawn into entirely new areas of

Delivered at the FAA Symposium THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM , at Oklahoma City, Oklahoma, U.S.A., 3-5 December, 1968, by D. Hyde, Engineering Training Manager, BOAC.

important technical responsibilities, such as the maintenance of tape controlled automatic checkout equipment, Nyquist plotters associated with the functioning of powered flying control units and even the sophisticated electronics of automated freight warehouses. The ancilliary tradesmen who are engaged in these activities may not be an aircraft maintenance responsibility in all airlines, but I am sure that you will acknowledge the increasing need for their skills to be equivalent to those working directly on the aircraft task.

A progressive integration within the systems of the aircraft is also an important factor. Although there have been great strides made in the development of automatic checkout equipment during the last decade, I do believe that we still rely on the basic trouble-shooting skills of the individual man in the vast majority of situations. I do not mean to give you the impression that we are still entirely governed by the "if in doubt, throw it out" philosophy of component replacement - but merely that effective checkout equipment has tended not to keep pace with the introduction of the more sophisticed hardware and systems.

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We are, therefore, faced with what often amounts to a conflicting requirement between reduced costs, or increased utilisation, and the maintenance work associated with these new systems.

As far as the external environment is concerned we have, of course, our airworthiness authority, the Air Registration Board, and the Board of Trade. In the training business we also have the Civil Air Transport Industrial Training Board. This is a new organisation which will probably be unknown to most of you, so I will describe its origin and functions.

It was established in March 1967 as the nineteenth of the industrial training boards which have been set up by the British Government in order to achieve the objects of the 1964 Industrial Training Act, namely:

SLIDE 3

1) to ensure an adequate supply of properly trained men and women at all levels in industry,

2) to secure an improvement in the quality and efficiency of industrial training

and

3) to share the cost of training more evenly between the companies in the industry.

The Civil Air Transport Industrial Training Board, therefore, is responsible for seeing that the quantity, quality and efficiency of training are adequate to meet the needs of the United Kingdom Civil Air Transport Business. Equity of training costs within the industry is assisted by means of a levy and grant system.

For these reasons the ITB will become the centre of activity on matters relating to Industry-wide manpower planning and forecasting. The only obligation on an employer is to comply with requests for information and to pay the levy; the Training Board is, therefore, a stimulator, and not a regulator like the ARB and Board of Trade.

In its initial training policy the Board is encouraging a "systems approach" to training by all sections of the industry, so as to ensure a proper relationship between the various component parts, including the training to meet mandatory standards. It also intends to reinforce safety practices in all training aspects, to encourage the maximum cost effectiveness in training, and to provide a forum for the pooling of training knowledge and experience.

Generally speaking, these Training Boards are beginning to achieve the three fundamental objectives of the 1964 Act. However, it is not unknown for these objectives to be overshadowed by the desire to play the "levy/grant game". It is also not unknown for some of the levies to remain unpaid, the farmers being the outstanding example of this situation !

The Training.

In a specialised industry which is characterised by a high rate of technological change and a high sustained rate of growth, the training needs of new starters can be quite differenet from those of experienced staff within the company. Uncertainties surround our main sources of ready-trained labour which are, of course, the aircraft manufacturing industry and the Royal Air Force. Political decisions on, say, the future of our airframe industry, or the restricted influence of the RAF East of Suez can have significant effects on the quantity of useful skilled labour available to BOAC "on the street corner" - as indeed can the sudden and unexpected closure of a major independent airline such as British Eagle.

Comparatively short term unpredictable variations in required manpower strengths - such as the ones we have faced during the last two winters as a result of the Boeing 707 wing re-work programme - have to be accommodated within the currently available labour market.

As far as long term changes are concerned, we make a big investment in apprentice training so as to ensure a supply of skilled manpower to meet our future needs. I will describe our experience and our plans in some detail.

In the Engineering and Maintenance Division of BOAC, or any other large international airline, there are a wide variety of tasks to be accomplished; we need craftsmen and technicians in large quantities, together with smaller numbers with higher levels of academic capability, such as our National Certificates and Diplomas or Bachelors Degrees in Engineering.

SLIDE 3

At this stage I had better define my terminology. Technicians are those likely to obtain aircraft maintenance engineering licences and

become Supervisors or higher; Craft (Maintenance) are those likely to work on aircraft, and some may achieve licences; and Craft (Overhaul) are those likely to be engaged on component overhaul.

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These requirements have led to the development of the four schemes within the apprenticeship pattern of Craft, Technician, Student and Undergraduate. Entrants usually start with the Corporation at the age of 16 and they are designated to an integrated four year apprenticeship of academic and practical training in one of the main trades. The Craft scheme also covers Carpentry, Upholstery and Painting specialists. Incidentally the undergraduate scheme also takes entrants at the age of 18 and we, together with BEA have pioneered a new five year Air Transport

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Engineering Degree course at one of the new Universities in London - six months of each year are spent at the University, followed by six months industrial training with the airlines, a so-called "thin sandwich". The other academic commitments are normally based on a "block release" pattern of one week

SLIDE 6

at College in every three weeks. In this way the theoretical approach in the classroom is progressively reinforced by integration with the practical industrial training and experience.

You will appreciate that the relative requirements for craftsmen and technicians are constantly changing. The need for a common and thorough grounding for all technicians, whether they are mechanical, electrical or instrument/radio/radar men, together with emphasis on diagnostic skills, dictates our technician course patterns. However, even now one can recognise a very wide variety of skills/knowledge requirements within the future technicians grades, ranging from those who operate automatic checkout equipment to the stated procedural instructions, to those who are able to trouble shoot and even programme the checkout equipment itself.

SLIDE 7 Starting this last September, we have increased our off-the-job practical training to cover the first two years of apprenticeship for the main trades. In this way we shall extend our initial training from just basic workshop practices, to cover aircraft components and their assembly into systems, together with the appropriate disciplines on the airframe side. Extensive use of simulation rigs will be made. Our rapidly increasing intake numbers - we started nearly 100 this year - would, in any case, have caused severe embarrassment to the production process if released on to the work areas after only the first year of basic workshop training.

We have therefore joined BEA in a joint venture to form the Air Corporations Engineering Apprentices' School. This is a project involving £2M capital expenditure which will give us a basic training facility for the first two years of apprenticeship in the main trades. We are due to start training operations there in September 1969 and within a few years we expect to have some 560 apprentices based on the premises, resulting from an intake of about 140 each year from BOAC and the same number from BEA.

During the third and fourth years of the scheme we will continue to rotate the apprentices through the relevant workshops and the hangars respectively. Visits to the technical sections are scheduled in between continuing College commitments and in-company courses at our Technical Training Centre. These last two years of the apprenticeship provide the opportunity for gaining specialist knowledge to the required depth.

In many instances we also encourage the continuation of appropriate College attendance after the statutory four year term of apprenticeship has been completed. In fact I would suggest that the length of apprenticeship is somewhat arbitrary, the current four years being

determined partly by the appropriate industrial norm; it certainly is not a sacrosanct period of time, especially where, as in our industry, training is a continuing process.

Moving now to a consideration of adult training, the emphasis in training for many maintenance and overhaul jobs has changed significantly in the last decade. For example, in the avionics workshop task we are not so interested these days in delving into the detailed circuitery of the components, but we are increasingly concerned in the quick isolation and replacement of a faulty "card" in order to achieve a rapid turnround and minimise the float of expensive "black boxes". However, I will concentrate my observations on the aircraft maintenance technician.

With the ever-increasing complexity of the task itself, together with the continual escalation in salaries, there are strong incentives to tailor technician's training strictly to a "need to know" basis for the job he has to do. This may sound a very obvious statement, but I am sure that many of you will acknowledge the dominating influence that externally and internally required standards have had in the training field. Such standards are, of course, absolutely essential, but I am merely pointing out that they can be unnecessarily high in some areas. Indeed if they are internal, it might even be fruitful to consider changing the actual standard; and I do not exclude from this the standards set by the trainers themselves.

Inevitably we come back, in theory, to a complete task definition and skills analysis in order that the "need-to-know" can be specifically stated. The definition of training requirements by line management is really very difficult in practice. One can get quite close to the [illegible]

solution by reviewing course designs with a couple of training staff who have practical technician experience and one or two technicians with current field knowledge. Let me emphasise the need for the training people to be willing to take a completely new look at their methods and course contents. Incidentally it is, of course, wise to have a member of the Inspection/Quality Control organisation directly involved in this "hatchet" activity. Nevertheless, if time permits a detailed definition and analysis will still provide the most comprehensive information, some of which could be used for other than training purposes.

Apart from training on specific equipments, we are also conducting a programme of supervisory training. The larger significance of incidents and delays due to faulty maintenance, with increasing aircraft size and cost, has led us to concentrate on the technical management aspects of the supervisors job. Starting with a refresher on the overall responsibilities and techniques available the subject of documentation is covered in detail and speakers from the Technical Records and Quality Control Units explain their own control systems and reporting procedures. By selecting staff from different work areas, and involving a senior member of line management towards the end of the course, an interesting and useful cross-fertilisation of ideas has resulted. Suggestions made during the courses have been actioned and improvements to the system have resulted. A well trained supervisory staff is certainly a key factor.

In addition to conventional off-the-job classroom training, increasing effort is now being applied in the use of audio-visual aids for on-the-job demonstrations during off-peak periods and when a specific need-to-know arises.

The impact of any complex written or oral instructions can be greatly enhanced by the use of a dynamic visual display. Closed loop films which are cassette loaded into back-projectors, thus enabling them to be used by any individual at the press of a button, are one solution. Another is the use of video-tape recordings in a closed circuit television system. In general you are more advanced than ourselves in the application of such aids, and I can best summarise their advantages by quoting an old Chinese saying "I read and I forget, I see and I remember, I do and I understand".

The Results.

Looking now at the results of our training patterns, let us consider firstly the achievements of our ex-apprentices. There has been an established apprenticeship scheme in both BOAC and BEA for nearly 20 years now - but remember that this means that the oldest of the ex-trainees are only now in their mid-30's. Clearly their full impact is yet to be felt, but already they are occupying a wide range of jobs in our Engineering and Maintenance Division, as well as related tasks such as Flight Engineering; in fact we are sometimes accused of training for too high an academic standard with the result that the technical offices get a disproportionately large benefit from our schemes. Certainly some of the "high flyers" are taking University Degree Courses and others have even completed post-graduate level studies in Air Transport Engineering, but the numbers in the shop floor areas are also beginning to build up. Surveys and opinions from the shop floor supervisors indicate, in general, a strong preference for the young ex-apprentice over the external recruits.

An important intangible benefit should result from better communications and rapport between, say, the technical offices and the production areas as these groups of young men move up the echelons of supervision and management.

However, there is one area on the office side in which we have had difficulty in attracting sufficient of our internally trained men until very recently and that is in the planning and production departments. The engineering development jobs are always consistently more popular. This problem really is a vicious circle as those who come to the end of their apprenticeship, or post apprentice technical training, see that there are few of their well qualified predecessors in the production side and therefore tend to shy away from these areas.

As far as termination rates are concerned we have found that, until several years ago, the wastage after completion of apprenticeship was approximately the same as for adult industrial staff. The pattern was also directly comparable, with high rates initially followed by a low constant rate after a period of some 5 years employment, by which time approximately half the original intake had left the airline. In the last two years there has been a significant reduction in these wastage rates. There are a number of influences at work simultaneously, but a predominant factor has probably been the availability of continued sponsorship for those completing technicians course Certificates during the first two years after apprenticeship - a time when the termination rates are normally highest. However, let me emphasise that we will always place a high value on those individuals who leave us to get experience in other airlines, but later rejoin the fold; we already have quite a number in this category.

In the area of adult technicians training, I hope that I have not given you the impression that there is no place for the classical approach of skills analysis, job description and measurement of initial and terminal behaviour, involving the detailed analysis and recording of the knowledge and skill content of all individual jobs performed. However, when the end products of costs, technical delays and incident rates due to faulty maintenance are pressing hard, an engineer's compromise solution can be the best investment. Line management must still have the responsibility for ensuring the effectiveness of training by :-

SLIDE 6

firstly, stating how they propose to use their manpower

secondly, making adequate allowances for training in their manpower budgets

and thirdly, sending their men on the courses that they, line management, requested.

As far as the future is concerned, training must form a part of an integrated approach to the whole problem of aircraft maintenance and overhaul; the image of the aircraft maintenance techni[illegible]an needs to be fully recognised and the development of automatic checkout equipment to its full potential will have an important effect on the combination of skills and knowledge required, ranging from the pas[illegible] monitor to the high level technician. Perhaps the only thing we can be sure of being constant in the industry is change.

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Slide 1

Autoland

Maintenance
Recording

Inertial
Navigation

Satellite
Communications

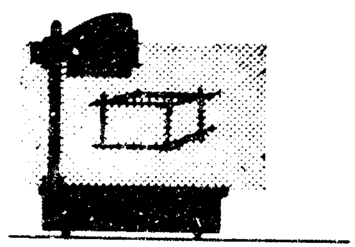
Electrically Operated
Flying Controls

Multi-purpose
Electronically Controlled
Fuel Systems

MORE SOPHISTICATED SYSTEMS

Slide 2

To ensure an adequate supply of properly trained MEN and WOMEN at all levels in industry.

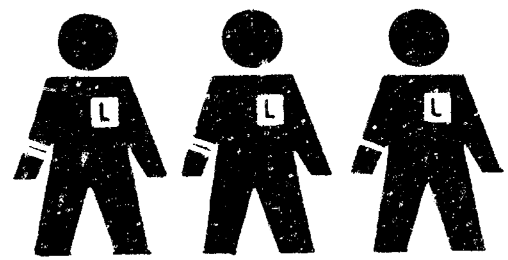


To secure an improvement in the quality and efficiency of industrial training.

To share the cost of training more evenly between the Companies in the industry.

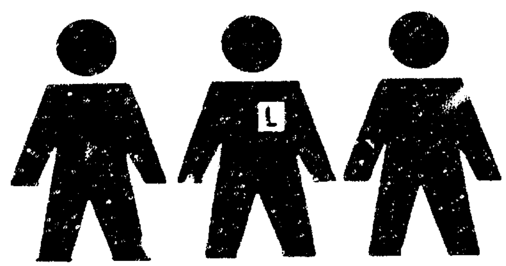
INDUSTRIAL TRAINING ACT 1964

Slide 3



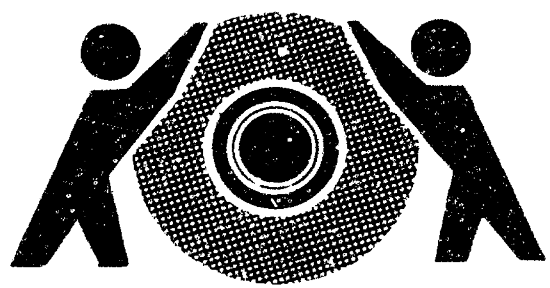
TECHNICIANS

Those likely to obtain Aircraft Maintenance Engineering Licences and become Supervisors or higher



CRAFT (Maintenance)

Those likely to work on Aircraft, and some may achieve licences



CRAFT (Overhaul)

Those likely to be engaged on Component Overhaul

TERMINOLOGY

Slide 4

	CRAFT	TECHNICIAN	STUDENT	UNDERGRADUATE
Start at age	16yrs	16yrs	16yrs	18yrs

Engine/Airframe, Electrical, Instrument, Radio/Radar.

CRAFT also covers Carpentry, Upholstery & Painting.

APPRENTICESHIP SCHEMES

Slide 5

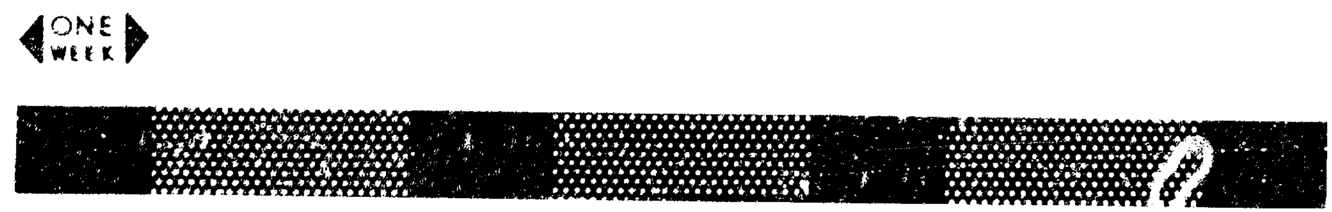
The City University, London

INDUSTRIAL TRAINING/EXPERIENCE SEMESTER

UNIVERSITY SEMESTER

AIR TRANSPORT ENGINEERING DEGREE COURSE

Slide 6

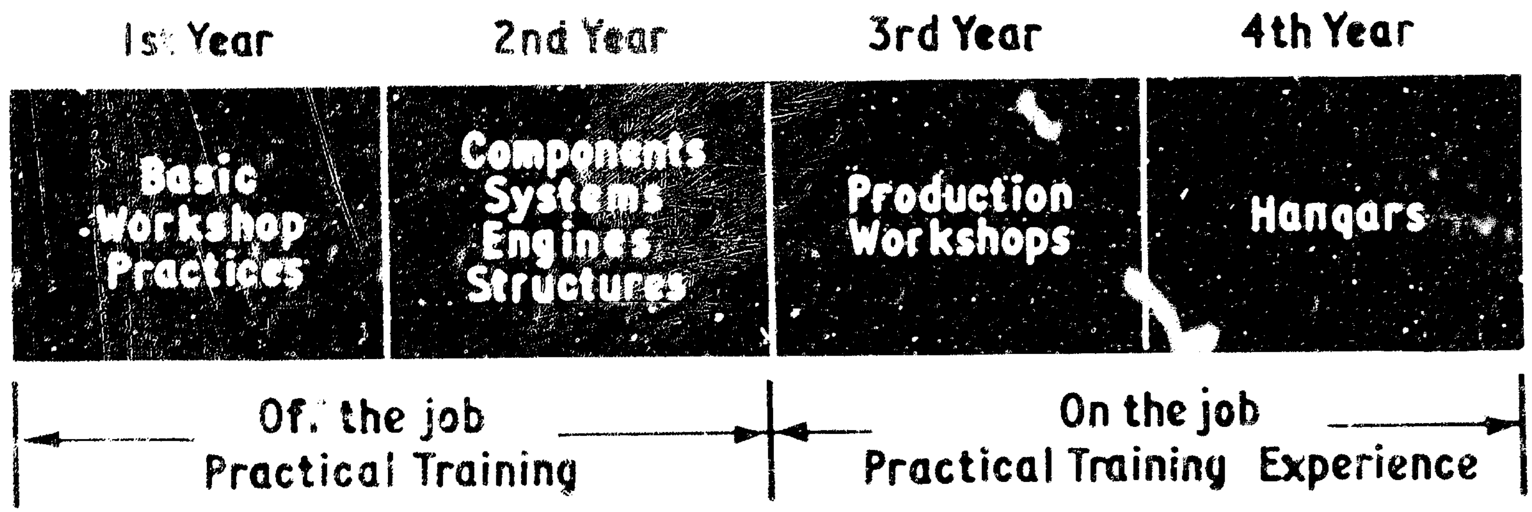


COLLEGE

INDUSTRIAL TRAINING/EXPERIENCE

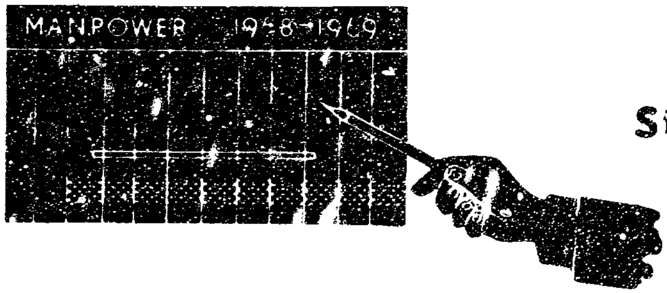
NORMAL 'BLOCK RELEASE' PATTERN

Slide 7



APPRENTICE TRAINING OVERALL PLAN

Slide 8



State how they propose to use
MANPOWER

Make ADEQUATE ALLOWANCES for Training in MANPOWER BUDGETS

Send STAFF on the Courses that
they (LINE MANAGEMENT) requested

LINE MANAGEMENT
RESPONSIBILITY for TRAINING
EFFECTIVENESS

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Project TRANSITION

I am indeed honored to be with you this afternoon.

The theme of the conference reflects the continuing need for highly trainable men as an essential ingredient in an aircraft maintainability system.

My purpose in speaking today is to tell you about an important manpower potential for you - the returning serviceman.

During this fiscal year and those following, over 900,000 individuals will be leaving the military services and joining the veteran's ranks.

I would like to give you a profile of these young people.

- They average about 22-1/2 years of age.
- About 75% are high school graduates.
- They have been through a disciplined experience.
- They have learned responsibility.
- Many have found a leadership potential they did not know they possessed.
- About 30% say they would follow a good job to a new location.
- They have their service obligation behind them.

Paper presented to the FAA Maintenance Symposium, THE MAN IN THE MAINTENANCE RELIABILITY SYSTEM, at Oklahoma City, December 3-5, 1968, by Col. J. K. Johnson, USMC, Office of the Assistant Secretary of Defense (Manpower & Reserve Affairs).

- They know that they live in a time when knowledge and skill mean job success.
- They want to make a positive contribution to American life, if the opportunity is presented.

In January of this year the Department of Defense established Project TRANSITION to help these men bridge the gap between military service and their reentry into civilian life. We recognize that in today's economy the return a man can obtain from a job is related to the amount of education and skill knowledge which he can bring to that job. We also recognize that the problem still remains one of getting the right men into good jobs where the demands are high and the wages are good.

So, the great task is to introduce these men into the types of technical training that are required to meet your industrial demands.

Under Project TRANSITION we set about to tackle this problem.

The President, in his Manpower Message to Congress in 1967, reported that he had asked the Secretary of Defense to provide maximum inservice training and education to men. He stated that he wanted all military service to lead to productive careers.

Following his guidance we first turned our attention to identifying the target groups. We established the following priorities:

- The combat disabled.
- Those with no civilian-related military skill.

  Many in this group are the combat men who have served in Vietnam and they form our major target group.
- Those with lower educational achievement.
- Those with civilian-related skills which require upgrading to meet the needs of potential employers.
- Those retiring personnel who need a boost to good job opportunities.
- Those who desire to gain a new skill.

While we keep these priorities in mind in developing our training programs, I must say that we have been quite overwhelmed by the response of all returning servicemen to the program. Between 65 and 70% of the men with six months or less of service remaining who plan on leaving the service tell us they want assistance.

Our program is designed to provide four basic services:

- Counseling to help men sort out the options available to them.
- Training to provide skills for which industry has a specific requirement.
- Education largely to provide an opportunity to complete a high school equivalency program.

- Placement assistance to link these men to civilian job opportunities.

We now have 254 installations in the United States and overseas where our program is in operation. We are planning to expand it further to accommodate as many men as possible.

I would like to tell you something about how we reach them

We provide a questionnaire to all servicemen in the United States and at some Air Force installations overseas who have six months active service time remaining. We do this for several reasons.

First, we purposely have concentrated our TRANSITION program in these last few months of service.

Second, we want to sort out those who desire to go on to a career as a soldier, sailor, airman or Marine.

Third, we wish to give these men some way of indicating the kinds of assistance they desire.

Our counselors examine these questionnaires, which are administered monthly as more men become eligible. After appropriate

discussion periods, the counselors then help to arrange for the necessary inservice training or education programs and job placement help.

We believe that these last six months are an opportune time for young men to start thinking about their future. These men are less likely to be transferred and can be easily reached. We have their personnel records, some evidence of how they have performed and what assistance they may need.

Our guiding principle has been not to duplicate what other agencies in the public and private sector can provide, but merely to bring these resources closer to the men before they scatter all over the nation. Let me demonstrate to you how this is now being done.

We have concentrated on a skill training program, since almost 70% choose to go this route rather than over the education path. Our first task has been to set up training programs which are responsive to the needs of business and industry.

We recognized that we would not be able to accommodate all men because of the time element or the availability of resources. But we have been continuously broadening the base of our training program.

We took a unique plunge. We have gone to the business community and have asked it to provide training on or near a military base in the skills for which it has specific requirements. This training is mounted and financed by the companies involved. The company supplies the instructor and equipment. We supply the manpower resource and in many cases the facilities. We have also asked industry to provide us with company training opportunities, or available jobs, for those who could not be given training prior to their discharge.

We now have some 50 large companies and some 400 smaller companies supplying us with training opportunties. The automobile industry represented by General Motors, Ford and Volkswagen of America have opened up their regular training facilities near some of our military bases. Men successfully completing these courses - usually running four hours a day for 12 weeks - are then offered jobs with dealers. While they are in training, company representatives and our counselors begin to line the men up for jobs near their hometown or in some other area of their choice.

Lockheed is preparing pipefitters in Tacoma, Washington, and IBM is preparing office machine repairmen. Several oil companies are training service station managers.

Sears, Montgomery Ward and J. C. Penney are offering training for jobs in their service departments, namely automobiles and appliances.

Beyond this, each installation has sought to involve local and regional industry near the base. This may include companies supplying limited on-the-job orientation or training in the plant or company office. For example, at one military installation, some 20-30 companies are providing this kind of assistance.

The response has been most encouraging. We gradually are building a larger training base. We are getting our men into very meaningful jobs. In turn, industry is getting men trained according to its own requirements. We feel that the whole economy reaps worthwhile benefits since these men are trained and ready, as soon as they leave service, to become immediately productive.

You will recall I mentioned our efforts to mount as broadly based training program as possible. I have just outlined private industry involvement.

I would now like to mention very briefly the contributions of the public sector.

First, we are using the training resources which are available on many military bases. We also call upon some Federal agencies to provide training. The Post Office Department and Department of Agriculture provide training for new postal workers and engineering field aides respectively. We also have 50 courses financed by the Manpower Development and Training Act funds of the Department of Labor under contract with private concerns or educational institutions for the training of service type personnel.

Government placement services are made available to individuals at the conclusion of their training. This is normally done in two ways:

- State Employment Services offices provide information concerning the employment opportunities in the area where the individual desires to settle.
- The Department of Defense offers opportunities in the Federal service to individuals through its computerized man-match program. The Civil Service Commission also offers employment elsewhere in the Federal civil service structure.

One word on our education program. We are trying to provide the academic subject training necessary to bring the men up to the 8th grade or high school equivalency level. We have also asked some colleges and

universities to offer on or off base courses which would be lead-ins to a college course for men who never have thought about attending college.

In establishing the program I have just described we have followed certain basic guidelines:

- We have decentralized operations so that industry can work out mutual arrangements with our installation personnel.
- We have asked commanders to arrange for on-duty release time for training when consistent with their basic mission requirements.
- We try to keep our training offerings consistent with overall industry needs and in areas where there will be a long term job requirement.
- We have enjoined our project managers to seek out local and regional training and placement assistance to the fullest extent possible.
- We try to promote mobility - especially among minority groups who would otherwise return to critical urban or rural environments.
- We try to provide some service, whether it is merely limited counseling and placement, to all servicemen who may desire partial assistance.

Where Do We Stand Today with Respect to this Program?

- From January through August we have provided job training or education courses for 20,000 men.

- An additional 13,000 are currently in training.

- Our goal is to try to reach approximately 500,000 each year by questionnaire, to counsel some 350,000 and to provide training for about 150,000.

Let me take a few moments to discuss your possible role in our program.

There are three approaches.

First, since we are training some men in job areas of specific interest to you, we might encourage men to participate in training programs you may now have, or may establish, near our military bases. We recognize that the training these men now possess are very specialized in nature. Yet, we feel that they can be trained quickly to meet your requirements, pointing ultimately to FAA certification if required. We are certain that many of our trained men would like to continue in the Aviation field. The men of our main target group also may desire to enter this field. They could do so through a course of training you may wish to provide on or near a military base.

Under this plan, men can attend these courses prior to their separation from active service. This means that DoD will provide the men and house and feed them. You may provide the training at your expense and conduct courses to meet your specific requirements. Of course I must reiterate that we are principally concerned about the men of our major target group who entered the service with no civilian skill and have not gained such a skill during their military service. We wish to increase their chances of meaningful jobs.

Another way you may wish to participate is by providing training for servicemen after their separation. Under this plan, prospective employers make known to the Defense Department those training programs that are available within their companies. These notices to the Defense Department indicate the skills for which training is being offered and the location of the training sites. The company also offers placement upon successful completion of training. These notices are sent to military posts and stations for the use of counselors in referring men to industry training programs.

A third method of participation lies in direct job placement of already trained men. The interested company provides Defense Department with notices of available jobs. These notices provide sufficient

information to identify the desired skills necessary for the man-job match. It also provides information for trained servicemen who may be interested in working for your company. Again, these notices are sent to counselors for use in referring men to your appropriate offices.

In all three of these approaches, we in the Pentagon would plan for you to work closely with TRANSITION representatives at nearby military bases to make necessary arrangements and to promote the interchange of appropriate information.

How many men are we talking about when we refer to men who possess some related, but specialized, aircraft maintenance skill?

During FY 68, the military Services released approximately 49,000 men. In FY 69 we anticipate that 45,500 will separate from active duty.

These men have skills that vary from the giant jet engine mechanic to the small utility aircraft engine mechanic and from the aircraft electrician to the instrument technician.

As most of you know, our military technical schools provide specialized training in maintenance. Many of our men have accumulated years of experience working at various levels of competence on military aircraft, within definite limits of specialization.

But when these men decide to leave the military Service, they find difficulty in finding employment in civil aviation because of the specialist nature of their training and experience. They cannot become certificated maintenance technicians without additional training.

In February 1967, FAA and DoD took initial steps to resolve the problem. A series of meetings were held to provide FAA with background information regarding the procedures used by the Military Services in training and using their maintenance men.

Representatives of FAA visited several military training centers to discuss the methods used in establishing and updating curricula, the skill training and practical factors testing, the production and maintenance of training materials, the methods of achievement testing, and the utilization of personnel after training.

Upon this basis, a tentative program was to be examined which would provide a means whereby military aircraft maintenance men could receive partial credit toward FAA certification.

If the proposed program proves feasible, I am certain that it will be attractive to our dischargees. We have many letters on file from our men who desire assistance in obtaining relief from the present methods of the certification process.

Indeed, a few of our TRANSITION trainees are attempting to prepare for the FAA examination for maintenance technician certification in vocational training schools.

We look forward to an early approval of the proposed program or to an alternative method of capitalizing upon the trained manpower resources who leave the military.

What I have presented to you here today is both an opportunity and a challenge.

It is an opportunity because it helps you to tap a very valuable manpower resource which is already well-motivated.

It is an opportunity in that it provides you with a means for tailoring a program to fit some of your unique requirements.

It is a challenge in that it helps you to find additional ways of helping these young men, who have served their country well, to find new avenues for their energies - avenues which lead to a productive, economic life.

It is a challenge in that it helps you to participate hopefully in a venture where the opportunity for innovation seems limitless.

I believe I have outlined to you here today enough of the program so that you might see ways in which you can participate.

We will be happy to work with you.

May I express my personal appreciation for the opportunity to talk briefly with you about Project TRANSITION. May I also extend to you the best wishes of Assistant Secretary of Defense, Alfred B. Fitt, who has the basic responsibility for this program.

332-966 O - 69 - 18

FAA Maintenance Symposium
Oklahoma City, Oklahoma
December 5, 1968

Avionics Reliability - The Goal of the Seventies

H. F. Harrison, Manager
Avionics Engineering
Eastern Airlines
and
1968 Chairman
Avionics Maintenance Conference

Gentlemen, the world has shrunk a lot during the past twenty years. Today, you can make a telephone call from New York to Paris within minutes, read the European edition of the New York Times whose text was transmitted directly from New York to the European printing plant via satellite data communications and you can turn to your favorite TV channel and see a riot while it's taking place in Timbuctu. You can get on an airplane in Los Angeles and arrive in Australia just a few hours later. I was even able to get to Oklahoma City from Miami in some six hours. To get here from anywhere, as you know, is a challenge. Gentlemen, time has shrunk. We feel so crowded now that world leaders are probing the far reaches of space while at the same time looking to the ocean depths for continued sustenance. One big reason the world has been shrinking is that our airplanes have gotten bigger and faster. Considerations of safety, comfort, economics and public interest have increased in importance. The application of reliable aircraft systems helped to make this progress possible.

We are about to experience another level of increase in our business. Aircraft speeds will more than double with the advent of the SST, passenger capacities will greatly increase with the inauguration of jumbo jets and we will make increased use of new technologies in just about all systems aboard these new transports. While we, today, make important decisions concerning equipment for tomorrow's aircraft, we have to make sure that we take a systems approach. This means that we must consider the application of tomorrow's equipment aboard tomorrow's aircraft. While great strides are being made in avionics through the application of integrated electronics, modular construction, advanced computerized testing features, we must not forget people. It is through people we must make the greatest strides.

New systems must be of sound design and be able to stand the test of time. There is no place in a modern aircraft for gadgets. We laugh at the style cycles of womens apparel which seems to have reached a new ultra high in the past year. Yet one sees the same pattern in some technical areas. We had the Gay Nineties, Roaring Twenties and here in Oklahoma the Dusty Thirties, and today in avionics we have the Monitoring Sixties. Many of us in the industry feel this may be as hazardous as the Dusty Thirties.

Mr. Waterman, Chief Systems Branch, Flight Standards Service of the FAA, at last years symposium held here November 9, drew a very interesting analogy regarding rule modification by the FAA. He stated that the FAA tends to be parrot-like in its approach to a new system in that the parrot will hold firmly on with one claw while the other claw has established a new position in a positive manner. I have a small word of c- ion to the keepers of the noble parrot. Please don't let him get attache too firmly to the branch of the avionics tree that is labeled monitor. It is very rotten, suffering from carcinoma and will soon break from its malignant growth of monitors to validate monitors. I cite you the recent radio altimeter designs where approximately 50% of the circuitry is devoted to monitoring.

We can make good strides through the applicati- of new technologies, more effective tra.nin-, close industry cooperation and better understanding between the airlines and regulatory bodies. I'll now discuss one element in greater detail as applied to RELIABILITY - THE GOAL OF THE SEVENTIES.

The past decade has seen the rise of flight directors, advanced automatic flight control systems, doppler navigation and other sophisticated avionic devices. We are now rapidly becoming involved with systems such as inertial navigation, area navigation, clear air turbulence, collision avoidance, data links and satellite communications. Sophisticated passenger entertainment facilities are planned for the next generation aircraft. Movies, stereophonic music and all kinds of announcement services. Just about everything short of dancing girls. Gentlemen, all these systems require integration into the airframe and must be interconnected. This means a great increase in aircraft wiring, connectors and splices.

What development in technology can be applied to maintain reliability with this increased interconnection problem? The multiplex concept? The first large scale application in the commercial aircraft of this concept will be the B-747 entertainment system. Proof of this concept will provide the basis for serial transmission of information to all related systems and instruments on the aircraft through a limited number of coaxial cables of high integrity. This will provide the flexibility of routing essential signals over alternate cabling runs and keep the requirement for redundant transmission circuits to the minimum....another key factor in overall systems reliability. It is also substantially enhanced through the close cooperation between the many airlines to provide standardization of avionic equipment.

Industry characteristics and guidance have been developed for years by AEEC, the Airlines Electronic Engineering Committee headed by Mr. William Carnes of ARINC. In addition to preparing these characteristics I am certain that many of all the branches of avionics have been kept abreast of all new developments by attending meetings of this fine organization. At the AEEC meeting in 1954 it became apparent that in addition to an industry avionics design group, some beedback was needed from the personnel who feed and care for all the fine devices designed by AEEC, some of which left something to be desired in in reliability and maintainability. In the first couple years Maintenance

Meetings were tacked on to AEEC meetings. As the attendance reached a sufficient level the organization became an entity. Attendance grew until at our last AMC meeting held in Tulsa, there were 315 present. Our original organization was called AEMM...the Airlines Electronics Maintenance Meeting but in 1966 was changed to the Avionics Maintenance Conference (AMC), which is an acronym for the Airline's Militant Comraderie.

AMC is a loosely structured organization which is run by a six man Planning Committee and one very important millwright who knows just where to squirt a little oil or which button to push. This millwright is Bill Smoot who has been our Secretary from ARINC since our inception.

Other members of the Planning Group this year are: (1) Jan Schoehuizen who heads up IERA at KLM; (2) another member of our Planning Group is John Glenn and John had things in orbit long before Mercury. John represents the regional carriers but since the Air West amalgamation, this region covers all west of the Mississippi river; (3) Our new member at large, elected this year, is Dave Foster of GMATS. (As a former President of GM, Charles Wilson, who admitted to foot in mouth disease said "What's good for GM is good for the country"). We, therefore, look to Dave for our program relative to the large corporate air fleets because what's good for GM is good for everyone; (4) Mr. Wesner of National also joined our group this year representing the Domestic Trunks; and (5) Allan Brown of TWA rounds out our Planning Group. Allan has done many good jobs for AMC in the past and we expect big things from him in the future.

In addition to our normal Planning Group, during the past year three Task Groups have been very active. Alan Carmel has headed up TG-100 which is concerned with Technical Documentation which includes Service Bulletins, Service Letters, and all types of manuals. While we can't really force a manufacturer to comply, sooner or later he may get the message at the market place. Ken Moe of United chaired TG-102 which developed our industry MTBF reporting system. The Europeans have reported reliability for some time with good results. Our third quarter report is now in process. Our most recent Task Group is TG-103 which covers Test Equipment. Duke Gentile of Braniff is the able task-master of this endeavor. Somehow we have to develop checkers to check the checkers, or in any case trace the lineage of our volts to the Bureau of Standards.

There may be solid barriers between the marketing departments of airlines during the rush of "putting something else" up in the air, but we of the AMC work closely together to keep that "something else" flying. We tell each other of effective engineering and maintenance ideas through our newsletter "Plane Talk" which is published monthly through the able editorship of Bill Smoot, our Secretary. Plane Talk covers unusual problems, fixes, and vendor Service Bulletins related to avionics equipment. On a quarterly basis, it now also publishes the equipment reliability statistics furnished by 28 airlines from all over the world. We hope to expand this coverage as the success of this program unfolds.

As most of you already know, AMC is an organization of airline avionics people who get together once each year to help each other with avionics problems. Part of our meeting is devoted to a symposium with presentations by experts in various areas that appear on the horizon. Symposium reminds me of a story.....one of my Project Engineers attended a communications symposium two years ago. He attended one particular session because a learned professor type researcher from Princeton's Institute of Advance Studies was to present a new approach to communications encoding. After 20 minutes of real long haired discussion and the showing of many equations on the board, my man knew what had happened but he was beat to the punch by another learned professor from MIT who stood up in the middle of the room to say..."Doctor, haven't you in fact reinvented the Morse Code all over again?" Back to AMC...well, we make sure that doesn't happen to us because frankly, we can't afford the expense of reinventing solutions to problems that have already been solved. Plane Talk, airline tie lines and our annual symposium keep the information flowing between airline technical people....even on an international scale.

I want to tell you about this symposium because that's the big event of the year in avionic maintenance and engineering. The next gathering will be held at the Eden Roc hotel right on Miami Beach this coming May. In preparation of this symposium, we, the users of airline avionics equipment, develop a set of questions directed to the equipment suppliers. These questions deal with specific problems, poor reliability and other important aspects relative to avionics equipment. This information collected from all member airlines is distributed to the vendors who try to work out answers. These questions are frankly discussed at the open forum held during our annual symposium. Often, we in the airlines receive good solutions to our problems. When we don't we tell the vendors to go home and do more homework.

Our vendors occasionally feel that we in AMC just stir up troubled air, but the best way to detect these turbulent currents and avoid them is to supply troublefree black boxes that just keep on flying. In fact, we in the AMC are probably the best salesmen for avionics suppliers with good equipment. I think that all supplier firms agree that the integrity of our friendly group is above reproach.

We also recognize that technology marches on. The symposium features for that reason presentations by industry noteworthies telling us what lies ahead and how much more the avionics tree is branching out.

As Chairman of AMC, I want to invite you to Miami Beach in May. Mr. Jim Hemingway of the FAA has joined us many times and hopes that many of you will join him this year. We feel that the avionics interface is rapidly becoming less well defined while our systems reach into nearly every aspect of the aircraft. Your support and understanding is important to us because that is the basis for permitting us to realize our goal for the seventies. It is through people we make progress.

MAN OF OUR TIME IN AIRCRAFT MAINTENANCE-

PROMOTION OF QUALITY BY MANAGEMENT

By

J. H. Michel

Assistent to Mgr. Inspection Division

SWISSAIR, Zurich, Switzerland

It is a pleasure for me to speak to you in this symposium, especially because this years theme, "Man in the Maintenance Reliability System - a Positive View" offers a considerable range of aspects that are worthwhile to be discussed.

The theme has attracted us to that extend that we decided to contribute a presentation of our views, our philosophy and experience in this interesting field.

So we are discussing man, man in our industry, that is, man in aircraft maintenance. But you will no doubt agree, we cannot discuss man in a particular trade before we have given consideration to the object that has to be handled by our man and to the task we expect our man to fulfill on the object, namely the objective, maintenance, because we can try to appraise man for his task only if we are aware of the prerequisites involved.

Now then, let us have a closer look at the object. For our purpose in this circle we are concerned with flying machines, machines that were devised, designed and built by men under application of advanced principles and techniques that the genius of man rendered possible. But when we spare a minute to contemplate on the subject of technical sophistication in advanced technology, when we consider the possibilities that do exist in the present state of the art, don't we run the risk of creating an instrument that is beyond proper control and handling by average or slightly above average human beings? Surely, advance in technology is a must but we must remember that the application of advanced principles only results in a revenue when the advanced principle is fully mastered and under control. Otherwise, to return to our industry of airline operators, we buy extremely advanced equipment, promising all advantages and excellent economy which in reality will eventually become a terrific headache as all the shortcomings, covered faults and forgotten consequences will have to be dealt with by the manufacturer and the operator at considerable expense.

As an operator we are not concerned with the manufacturers' slice of the cake, our concern is our big slice, grounding of aircraft for troubleshooting,

calling in specialists, representatives, devising ideas and means to overcome the trouble, attempting temporary measures, taking care of the modifications that will as a consequence be issued by the manufacturers etc. etc. or rather blunty and short, loosing money instead of making money with equipment in which millions of hard dollars were invested. Do we not all agree that the aircraft we buy from a manufacturer should be matured and technically consistent? We realize that this claim is rather a harsh one but history shows that there never was a plane designed and built without no end of service bulletins to follow.

But since the object of our discussions here is man and maintenance, we will not further dig into the design and application of advanced technology by the manufacturers.

However, there is another aspect connected with the object which must be looked at in this context, namely the fact that the design on paper of an aircraft has to be put in practice, in other words, that the aircraft proper has to be built.

There again we have men who do the job. Some do the work with utmost care, concious of their responsibility, some just do it to earn good money to keep them well alive. Now lets have a look at the consequences of this combination of human beings taking part in the assembly of a highly advanced flying machine.

Can you be sure to buy an airplane which is free of defects, such as missing bolts, prestressend stringers and skinning, loose terminals etc?. to mention a few. Of course the manufacturers are aware of this fact and try to control it by throwing a force of inspectors into the battle, but who guaranties that all the inspectors are inpeccable and don't miss one item or the other? Our experience will confirm that flaws will pass, however many inspectors under an economy-oriented management are possibly put on the job.

So much for the object, now lets go on to the objective of our considerations. What is maintenance? Webster defines maintenance as meane of support or sustenance. Now applied to our object, the aircraft, we might extrapolate the definition in saying that maintenance of aircraft means sustenance of the proper condition to keep the aircraft operational, that is, in running condition, or to sustain its operationability.

The next question that arises is of course how we can achieve this task. There again we have to make use philosophical contemplations. How do we keep an advanced contraption like today's airplanes in running order?

Under the presumption that our object, the aircraft, is a top quality product of mature design with no flaws at all, the problem is an easy one. Maintenance would be reduced to servicing consumable items like oil, gas etc., to inspect parts and assemblies which are subjected to wear and tear, to be more explicit everything that is subjected to mechanical friction and to replace worn parts. Unfortunately our object does not meet this ideal standard. Therefore the problem to keep an aircraft in sound running condition is getting more and more involved. We have to take care of a considerable number of unknowns, we have to make use of experience, we have to critically review the design, we have to monitor construction and a lot more to enable us to determine the minimum requirements for maintenance. We all know that a considerable amount of the basic work in determining the requirements for maintenance is done by the manufacturers and the maintenance review board, who are dealing with actual facts derived from endurance and fatigue tests as well as assumptions based on long term experience.

However, a lot more must be taken in consideration by the operators of a maintenance base. Since we all are dealing with unknown quantities we forcibly tend to do too much to be certain to be on the safe side which means cost and more costs. With the experience accumulated over prolongued periods of time we will be able to gradually reduce the maintenance activities in zones and systems that prove their reliability. On the other hand with the increase of hours accumulated on aircraft we have to take fatigue, further wear and tear problems in account which again may necessitate intensification of our maintenance efforts.

To sum up our review of maintenance we can say that maintenance of an aircraft consists of taking care of the known items subjected to wear and tear as well as coping with unknown quantities in the sense of preventive maintenance.

So we have dealt with the object and the objective of our theme, we have tried to discuss some of the major aspects of object and objective. Now let us proceed to the most interesting and most variable factor, to the human being, whose job it is to fulfill the objective.

From the above considerations we realize that pretty much is expected from man earning his livelihood from maintaining aircraft. The question now is, do we get what we expect? In general the answer must be yes, after all, airplanes have been maintained more or less successfully from the advent of aviation over half a century ago up to the present time.

But here again we must take into consideration that the task of maintaining a flying machine, namely the upkeeping of its operationability is the only thing that remained the same, the techniques and ways and means of carrying out the task continually kept changing with the technological advances made in the industry. So nowadays we really are up against an agglomeration of advanced systems in a highly developed framework that is already difficult to visualize not to speak of, to fully understand.

So, returning to the individual who has to take care of todays flying machines, of their systems and components, we will agree that he has selected a way to earn his living which offers quite some challenges to him. We can try to define the characterial properties that are required to make him a satisfactory aircraft maintenance man. Just a few adjectives as consistent, reliable, interested, thorough, perhaps devout, will give a very basic description of the ideal character who should be capable of doing the job.

We all know that even the best man has his moments of distraction and because we know this from experience, we have devised ways and means to overcome the risks involved in this very human inconsistency. We have created the inspector whose duty it is to discover the slips of the people carrying out the tasks of maintenance. Now then, lets face the situation and lets review our personal experience quickly, do we not find an instance, probably not far back, when we were just lucky that an undiscovered flaw didn't result in some critical failure of the other. So we come to realize that even a well trained inspector may miss one item or the other. But why is this so?

Well, lets have a look at the ambiance in which these things happen, lets have a look at the time we are living in, our time, which has its influence on us all, good and bad.

We all realize that we live in a period of time that appears to be extremely fast running, so fast indeed that sometimes we get the impression that we cannot achieve our goals in business hours and in our past-time. We live in a period of great achievements in all sciences and technology, we live in a time where Jule Verne's and Aldous Huxley's utopical prophecies are gradually getting materialized, in short we are witnessing and taking part in a breathtaking period of time.

Thanks to highly developed communication systems we can take part, remotely though, yet live, in events taking place almost anywhere on our world, comfortably seated in an armchair in our living-room, watching the TV screen.

By means of radio and the press we get informed about almost everything, close and remote, we get stuffed with information on events important or unimportant. We get fed with man made dreams or thrillers from the entertainment industry free of charge FOB our living-room, the only trouble being, to select the channel.

We work fewer hours than our fathers did and get paid better. Todays ecconomical systems make it possible to buy almost anything we dare to dream of, even when we are short of cash, as almost every commodity can be obtained on a deferred payment plan and is readily advertised as such. No end of opportunities are offered to us for diversion. With this great time of ours the development is not exhausted, new standards are established such as extreme interpretation of personal freedom, resulting in the abolishment of taboos that used to be the backbone of society some decades ago. Just consider the side effects of our life engineered to appear carefree, consider what it means that the pay on friday night or the monthly salary does not belong to you anymore before its earned, as a number of installements are due. You will no doubt agree that our time, the enviroment, has an impact on behaviour of man, has an impact on todays society. When we get to realize how much is offered to us in the field of diversions, in the field of popular education, we find that our time must appear fast running, taking the mass of interesting items and diversions as well as our consequential worries in account that take up a considerable share of the time available. They may take command of our sparetime, and may be, some of our duty hours, and there it is, the crucial point, the mind may not be at the job that is got to be done.

So what can we do to prevent this, applied to our industry, dangerous or even fatal situation?

The answer, quite generally speaking, is simple enough, we got to compete with the temptations of our time, we got to make the job interesting, more interesting than the diversions of our time.

We have already come to the conclusion that maintenance of today's airplanes is a very interesting job but we have to take in consideration that maintenance partly consists of a long chain of interlacing actions that can be called routine work and there is our problem, how can we make basic routine work interesting? To my mind, this can be achieved by guided training of our maintenance men. We have to make them realize why for instance a bolt must be torqued to a certain value, we have to make him understand the consequences of an uncorrect torque value in the wider sense. We have to devise methods of tuition in simplified stressanalysis so that he will be able to imagine the consequences of a loose or just hand tightened bolt. We have to get our men system minded, we have to make them aware of the consequences of a cable interfering with a hydraulic tube for instance, to name an example.

In short, we have to make our man concious of systems and structures and their weaknesses as well as of possible consequences of improper installation. We further have to train our people to realize that a maintenance plan with all the job cards does not cover all unknown quantities. Therefore we have to get him interested not only into the item called for on the job card, but at the vicinity of the item, because it is there where we expect him to discover the unexpected defect!

Now then if we succeed in interpreting the routine jobs in the mentioned way, we should be able to create an interesting world for our maintenance man inducing extra efforts to do a good job.

So we can promote the quality of work our maintenance men accomplish by getting them interested in their work, by making them understand why all this apparent routine has to be carried out to close limits. But is this enough?, do we get the best results from this kind of ways and means to capture the attention of our maintenance men?

So let our minds return to the good old times, to the spirit of the early days of technological evolution, when craftmen produced technical contraptions, alone or perhaps assisted by a helper. In these days one could not delegate the responsibility to some inspecting individual, as none existed. It was the craftman's own responsibility to create a good, reliable and sound product. Thus, the well known pride of the craftmen in that period was created. Transforming this idea into our time this means nothing else than delegating the full responsibility for an operation to the guy that performs it.

Now this is easy to state, but how can we get this idea into practice? First of all we have to get our maintenance men to realize that the responsibility is theirs and nobody else's.

We further have to make them understand that their work will not be checked. We have to make them aware of the importance of the fact that a job must be done right and complete, however small it may seem, we have to make them aware of possible consequences when this is not done so. Thus we can create a certain pride which, by virtue of the fact, is of great importance. Thus we make him realize that his contribution is a link in a long chain of tasks that make maintenance, and his pride will not permit that the weakest link should be his.

But we have to realize that we cannot preach delegation of responsibility without actually doing it, that is, we have as a consequence to reduce or change our inspection efforts, or better to adapt the system. We have

to demonstrate to our man that his work is actually accepted without reinspecting it. Otherwise we attain nothing, as the maintenance man will feel deprived of his pride, he will be disappointed because obviously we do not trust him and consequently he will loose interest, which means that even our first goal will go down the drain.

This sounds as if we could do without inspection at all, a funny statement from someone representing the trade of inspection. Now then, we all know that even the best man has his worries, his depressions or diversions. We further know that there are some vital systems in which the slightest error could result in consequences beyond our imagination. That is exactly where our force of inspectors comes in, in duplicate inspection and in surveying critical areas selected from experience and on percentage checks which may be planned individually or decided on, on the spot, depending on our observations.

Now to return to the delegation of responsibility to its one and only proper place, to the originator of a product, we will review the suggestion under consideration of systems that already exist in our industry. For this we have to reconsider the question of delegation of responsibility in as much as hierachical considerations have to be taken in account. We have to look into the forman, leader, man-on-the-job relationship. There, the delegation of responsibility rests with superiors, after all these are the people who know their men, who can best judge their capabilities. So we may select delegation of responsibility to the man at the job in one case whereas in an other case the foreman will check, at his own discretion, one or the other job of some of his subordinates as he will find necessary. Now of course this is not a stationary matter, I should say, it is a continuous development in training. Neverless, the man at the job will consider the direct check of his superior less humiliating than an inspectors check since he knows that his superior will have to give him the guidance and the training and consider that kind of check as ways and means of verification, providing that it is properly done.

Now let me tell you some of Swissair's experience in our effort to promote quality.

Some years ago a gradual degradation of the quality of work accomplished by our maintenance was observed. Careful investigation of the causes of this phenomenon revealed that above all two factors mainly contributed to the prevailing situation, namely the "couldn't-care-less-attitude"

of some maintenance men, induced by the fact that almost every item or operation of important nature was checked by an inspector after accomplishment and, as a consequence, the fact that nobody knew exactly who would be responsible for any operation accomplished by maintenance.
The maintenance men, and above all their superiors, unanimously were convinced that the responsibility was with inspection, the final controlling agency, whereas inspection argued that this could not be the case as quality can not be inspected into a product.

Determined to put an end to this very unsatisfactory situation the manager inspection division decided to clarify the situation by the application of a hammer-blow action. He went to the manager aircraft maintenance and declared that his inspectors would be withdrawn from their present field of activity of inspecting the work accomplished and stamping the job cards accordingly as of tomorrow. He explained his reasons for the decision and made the manager maintenance fully aware that the responsibility was now his and nobody else's.
This caused of course a considerable row and a handful of reproaches to the effect that this was not way of cooperation in a company. However, the manager inspection did not retreat an inch from his point of view. The inspectors were briefed accordingly, they were instructed to have their eyes everywhere to keep book of their observations and to report critical flaws to the manager inspection.

Well, that was the hammer-blow. And the result? Well I guess some superiors of maintenance had a sleepless night or probably some more but somehow they succeeded in passing on the evil news with the necessary instructions to the men on the job and their direct superiors as within 24 hours the quality of work performed was raised by a considerable margin in an effort to survive, so to speak.

Inspection personnel were present in the maintenance area but took no apparent active part in the work, line personnel had to carry through their duties and had to carry it through properly. Undisclosed checks by the inspectors revealed very few flaws but one thing became apparent, the inspectors present, but seemingly not active were approached as consultants whenever a maintenance man or a forman was not quite sure how to do a job correctly.

So gradually the new concept with the defined responsibility and all its consequences was accepted. The higher ranked superiors who first opposed it had learned a lot, they had, under the pressure of the situation become aware of the real qualities of their subordinates,

they had realized that one or the other foreman did not meet the characterial properties required for his position and had taken the necessary measures to ensure that they could in future rely on their cadre. Lateron they created their own check-system by the introduction of lead mechanics, recruited from the ranks. The duty of such a leader is quite appropriate to his connotation he has to lead a group of maintenance men, he has to distribute the work among his men, he has to check their work, or perhaps better he has to train and instruct them to carry out a perfect job.

These leaders, incidentally, were trained for their work by old foxes of inspection, who passed on their experience and know-how with considerable success.

Looking back at this hammer-blow action, or perhaps blackmail as you may choose to call it, it is evident that the responsibility is now there where it must be, with the man on the job. The checking of the work accomplished, where necessary is carried out by those whose task it is to do the job and as the experience of our inspectors whose eyes are everywhere will confirm, with quite some success.

To end this presentation I can say that we have achieved a considerable inprovement in the quality of work accomplished by our maintenance men by training them, by giving them the responsibility for their work which they have accepted.

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A GENERAL AVIATION MECHANIC
LOOKS AT THE MAN IN THE MAINTENANCE RELIABILITY
SYSTEM

The description or a definition of the General Aviation mechanic today would be an impossible task. Even an accurate average age of the General Aviation mechanic today is not available. One of the latest complete studies of the aviation mechanic was published in 1963. At that time, it was admitted that nothing average for the General Aviation mechanic was established. The General Aviation mechanic was represented by a union or any large employer. He is scattered to the far reaches and remote areas of this country and the world.

The General Aviation mechanic is regulated by the Federal Aviation Administration. At the present, he is tested and licensed the same as any aviation mechanic. The qualifications are the same for all aviation mechanics.

The Airline Aviation mechanic generally works on one make and model aircraft and is seldom expected to be an authority or even qualified on more than four makes and models of aircraft. The General Aviation mechanic, on the other hand, generally works on at least three makes and numerous models of aircraft. The General Aviation mechanic is expected to be qualified on any aircraft based in his area.

In general use in General Aviation today we find aircraft with a top cruise speed of 75 miles per hour through a top cruise speed in excess of Mach .82. Also in general use in General Aviation aircraft today we find numerous types of reciprocating powerplants and the most modern types of turbine powerplants. The General Aviation aircraft today also contain systems of old forgotten types through the most modern designs.

Truly a General Aviation mechanic is a magic person. Let us take a look at a few of the problems a General Aviation mechanic faces in his role in "The Maintenance Reliability System."

The Mechanic Looks at the Job to be Done.

As the General Aviation mechanic reviews a project or a job to be done on an aircraft today, he must be ever mindful of the many varied skills and knowledge levels that will be encountered. Too many times he will overlook major problems that will be involved with the scope of the work to be performed. He is becoming aware of the lack of technical knowledge and skill that may be needed. Many unforeseen problems may be discovered. As an example, even the simple process of a spark plug change or an oil change

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on an engine today may present itself with the problems of Engine Major Overhaul. The skillful eye of a conscientious trained mechanic may prevent impending powerplant failure.

Familiar with the critical shortages of trained mechanics, he tends to be lax in one of the major roles of the General Aviation Mechanic. That role is the one of "Preventive Maintenance." This perhaps is the most important role the General Aviation mechanic plays today and will play in the future. The problems presented by skillful evaluation of symptoms found by "Preventive Maintenance" are more important than the actual repair itself. Once the area of trouble is located, he has books to tell him what to do next. Of course, all popular maintenance manuals have "trouble--shooting" sections. This section of any manual is only as good as the man who is using it. In all cases they are only a guide for the trained mechanic's thoughts presenting one problem at a time.

The Mechanic Looks at the Tools He Uses.

The evaluation of any job to be done is not complete without careful thought being given to the tools needed and the tools available. It is often very hard for the "front office" and the customer to believe that he cannot safely change a tire. This sounds ridiculous, but one must realize that about fifteen different jacks are presently needed by the General Aviation aircraft in use today. Also special sockets and torque wrenches may be necessary. The best thing the General Aviation mechanic can do is say "no" when he encounters jobs he has not done before and does not have the proper information to perform these jobs. Too often, men will try to fabricate tools or make-do with things that lead to major problems and sometimes great expense.

The Mechanic Looks at the Manuals He Uses.

Publications and manuals have been formerly mentioned. The use and context of these manuals vary greatly. Almost any established shop today has a library of very valuable information. It is suggested that the size of an average library today contains about five hundred manuals, technical pamphlets, and drawings. The papers may range in age from thirty years to present publications. The use of these publications vary almost as broad as their scope. Standardization of presentation of a manual may be a goal, but it certainly has not even approached a fact. Many times the mechanic's helper will fix the problem before the mechanic can locate it in the book. Of course, this leads to the fact that most General Aviation mechanics refer to the manual after all else fails.

The information found in some manuals does not always lead to safe practices or conform to laws of common sense. By the most part the printed information may be relied upon but the General Aviation mechanic must always be mindful to watch for obvious mistakes both in printing and context. Because of the time and space limits, classic examples of these obvious errors will not be presented here. Some of them will scare you.

The Mechanic Looks at the Product Support Furnished by the Manufacturer.

The General Aviation mechanic looks at the new aircraft delivered from the manufacturer as a completed complex product. Several of the popular manufacturers today admit that the final manufacturing process is completed by the General Aviation mechanic in the first hundred hours of operation of the product. The manufacturers are making sincere attempts to support this product, but many areas of general confusion still remain. It is common practice to receive single engine aircraft from the manufacturer that has less than one half hour of flight test by the factory and complex multi-engine aircraft that has less than one and one-half hours of flight test. With such production schedules, the manufacturer has to depend a great deal on the General Aviation mechanic.

The manufacturers **have** established warranty programs to help the dealer with expenses on warranty work. This program does not totally protect a dealer. It is an accepted industry fact that dealers have gone broke through warranty programs. This places a great deal of pressure on the General Aviation mechanic and in many cases his proficiency determines whether his employer makes a profit or a loss on a sale.

The manufacturers are improving their product support but this is perhaps one of the most lax areas in General Aviation today. For example, it is not uncommon for new engines or airframes to be in use as long as six months to one year before parts books and service manual are available to the mechanic. This is a disturbing hinderance to mechanics as it slows down their production rate immensely.

The proof of any product is its performance after it is delivered to the operator. Close coordination between the General Aviation mechanic and the manufacturer is essential to the continued sales or operation of any particular product. At times the General Aviation mechanic runs into so much red tape and paper work that this continuity is lost. The importance of a General Aviation mechanic's attitude and the manufacturers assistance is often overlooked in seemingly minor problems that later become major ones due to lack of cooperation. It should be one of the highest goals of a General Aviation mechanic and the manufacturer to constantly improve their personal relationships. In the past many good products have gone by the wayside because of the deficiency of proper field service.

The Mechanic Looks at the Test Equipment.

As aircraft increase in complexity, the use of special test equipment is, in many cases, very expensive. The General Aviation mechanic and his employer have to constantly evaluate the need and use of test equipment. A careful study of the cost, availability, and expected returns from any item of test equipment must be made. The mechanic has to make this decision and then abide by it. The General Aviation mechanic who has complex equipment but not the skill to properly operate it is worse off than the mechanic who does not have the equipment. In many cases, it is best for the General Aviation mechanic to

turn the job down and not overextend his knowledge and pocketbook. In many areas agreements between competitive operators and mechanics are being made so that complex test equipment may be profitably operated for owners in the locale.

Each part of test equipment must be constantly maintained and kept up to date with basic modification. The test equipment most people started with was military surplus equipment. On the whole, the equipment is older than the mechanic who is using it. The necessary equipment for modern day aircraft is no longer available on a surplus market. Each individual piece of equipment must either be fabricated by the mechanic or purchased from a manufacturer. The General Aviation mechanic must carefully evaluate all of his test equipment, both old and new, and be forever alert to the indication of a malfunction of the equipment. As aircraft development advances technologically, the test equipment one uses becomes essential to safe and profitable operation of modern aircraft.

The Mechanic Looks at Inspection, Repair and Parts Accessibility.

General Aviation mechanics are generally convinced that manufacturers constantly connive to design aircraft that are inaccessible and harder to work on. A prevailing opinion is that the design engineer is the immortal enemy of the General Aviation mechanic. As almost anyone would agree, these opinions have sound basis. Too often a mechanic spends four hours or more getting to a unit to replace a filter or normal service item that should take only ten minutes. Examples are simple instruments that happen to have two very useful post lights mounted in each upper case lug. The aircraft owner refuses to pay the four hour labor charge for two screws and two lights that are in plain sight. The result is another enemy for the design engineer who did not even know someone had placed a post light in his instrument. Many problems in this area are the basic like of productive communication between the design engineer, the lighting technician, the interior design people, the owner, and the mechanic.

The General Aviation mechanic really upsets a new aircraft owner when he removes all of the glued on carpets and upholstry trim from his beautiful aircraft. Of course, no conscientious General Aviation mechanic will accept the responsibility of all of the fuel lines, gear boxes, control cables, and hydraulic units under the floor panels without careful inspection. Because of increased aircraft performance and the problems encountered with inspection plates in stressed skins, the design structurial design and placed them in the aircraft. Then comes the interior design people who are given the job of beautification within a budget. The result is another enemy of the General Aviation mechanic.

As performance on modern aircraft increased, the repairability of many parts and items become more critical. Parts that used to be made of simple materials are now heat treated or made on an exotic metal. The General Aviation mechanic must constantly be alert to these units which he does not have the capability of accomplishing a simple repair. In future years this will become an even more complex problem. Now is the time for people in positions of leadership to start instilling these new ideas into the General Aviation mechanic.

The Mechanic Looks at Improved Design Techniques.

The General Aviation mechanic is constantly subjected to new design techniques. In all cases, the manufacturer means well and is attempting to reduce the costs and increase reliability. In the past few years, great strides have been made in this area and more are expected in the future. Like all new ideas, some of them arrive with new products that cause more problems. Many new designs have fallen by the wayside because the mechanics involved did not understand their function and were not informed as how to properly service them.

The Mechanic Looks at Records and Reports.

Perhaps one of the most important items that will help the General Aviation mechanic solve a problem is the use of a report. Without some device to receive problems from the field, the manufacturer has no way of knowing a problem exists. The manufacturers, in most cases, furnish the mechanic some type of reporting form. This is fine, except he never seems to have the right one.

All malfunction and defect report forms basically contain the same information. It is a shame that the mechanic does not have one form that would be acceptable by everyone. The Federal Aviation Administration needs their form, the engine manfacturer needs their form, the airframe manufacturer needs their form. So goes the paper mill of the General Aviation mechanic. It is easier to forget the problem and not even mention it to anyone.

When a mechanic undertakes to report an unairworthy defect in a modern aircraft, he had better have at least ten hours spare time on his hands. By the time he reports it to everyone who should know of the project, he has writers cramps and then he realizes that he does not have a record copy of what he just reported. Each report attempted to say the same thing but the format was entirely different. If he only sends one report, he always manages to send it to the wrong place or person and the effort was wasted.

The Federal Aviation Administration requires that the owner of aircraft keep current and complete records. With an excess of one hundred thousand General Aviation aircrafts in service today, I suspect that at least one thousand different types of records are in use. These all must contain the same basic information, but the format is a master crossword puzzle. No industry standardization appears in records kept. Each manufacturer has his own concept of log book format. In one instance, the VOR omni range accuracy check appears to be more important than the recording of the last annual inspection. Unknown is a single manufacturer who furnishes a log book that lists the chronological listing of Airworthiness Directives as required by the Federal Aviation Administration since 1957.

In most General Aviation shops at least one mechanic devotes fifty percent of his time to reports and records keeping. In most cases this is the chief or authorized inspector and the most experienced and qualified mechanic in the shop. Aircraft today contain so many different forms, no one except the most

experienced mechanics are capable of properly completing the necessary and required records. Standardization of these forms would allow secretaries to be trained to take the place of many General Aviation mechanics tied up in his own paper mill.

The Mechanic Looks at Basic Training and Technical Upgrading.

Several years ago we depended upon the military and the schools to train our basic mechanics. The military trained mechanics have decreased in the last several years. In fact, most of these people are specialist and have not been offered the background necessary to become a licensed mechanic.

The shops or operations who employ large numbers of specialists do use some of the specialists as repairmen. These repairmen are useful in complex operations and large shops. The average General Aviation operator cannot depend upon enough exclusive work to employ large numbers of specialists.

General Aviation does receive all of the school trained mechanics that they can absorb. Since the pay scale and working conditions in General Aviation is normally lower than that of the airlines, only a small percentage of school trained mechanics enter General Aviation as a career. As a result of mechanic placements, the schools naturally lean their training toward the needs and operations other than General Aviation.

The experienced mechanic needs to be up-dated in his training and needs to be trained to service the new systems being introduced into General Aviation. To assist in this area most General Aviation manufacturers have training programs designed for the average General Aviation mechanic. In fact, very large sums of money is presently being spent by at least one major General Aviation manufacturer to produce comprehensive training programs. Most General Aviation aircraft manufacturers realize that their product is no better than the mechanic who service it. Currently these training programs are the only way the General Aviation mechanic may up-date himself and learn the new systems currently in production.

Some large General Aviation operations have training departments that devote full time to up-dating and training mechanics. Of course, programs of this nature are not common place. They are, at least, and indicator of trends toward the importance of training. Even small General Aviation operators are scheduling regular sessions of training on monthly basis. These small General Aviation operators are welcoming any and all aids in training that they can enlist from any manufacturer.

The on-the-job training program is the most commonly used system of training General Aviation mechanics. In some areas of the country, this program is currently being used in high schools supplemented by what ever instructional material the high school may have available. Since the General Aviation mechanic is strong in demand, the General Aviation operator is supporting and seeking any type of aid or help available.

The Mechanic Looks at his Housing and Work Facilities.

The most common problem of the General Aviation mechanic today is proper and adequate housing. Very few mechanics are not looking for improved housing for their shops. Due to the fact that most of the country's airports are crowded and the land and buildings expensive, future relief in the housing problem appears dim. In may areas the operators of maintenance facilities depend upon doing part of their work outside when weather conditions will permit.

It is not uncommon to find mechanics working in "T" hangars and on the ramps in the southern areas of this country. Some of these mechanics are "independents" or "moonlighters." Many large operators have crews working under these conditions because adequate housing is not available.

In several areas of this country, General Aviation mechanics are working out of mobile shops on the back of pickups and in trailers. These mechanics are doing all types of maintenance on various aircraft from mobile operations with no permanent housing at all. This practice is more common in remote and scarcely settled areas but they are not unheard of in the high density areas.

The Mechanic Looks at his Work Environment.

It is common knowledge that the aircraft hangar is the coldest place in the winter and the hottest place in the summer. If the wind is blowing thirty miles per hour outside the hangar it is blowing forty miles per hour inside. My intentions are not to be a comedian but sometimes a plain statement of fact appears comical.

The pure necessary design of an aircraft hangar with wide doors and high roofs does not lend to economical environmental control. Also in the dusty areas of the country this basic design means very poor dust control capability. Large sums of money have been spent in many areas of the country on hangar environmental but few mechanics are satisfied. Surely some industries are worse off environmental wise but very few of them fuss as much as the General Aviation mechanic.

The Mechanic Looks at his Limitations.

Perhaps one of the most difficult statements for a General Aviation mechanic to make is "I do not know." This pride possessed by most young mechanics sets him aside from many professional people. He has been schooled and tested on all aircraft from the C-3 Aeronica through the largest aircraft in current production. He has a ticket in his pocket that proves he is an authority on anything that fly, without God's initial design and blessing. Twenty years ago a mechanic could form this attitude and get by with it. Today the picture has drastically changed. All mechanics should be aware of the Federal Aviation Administration regulatory articles in this area but since the Federal Aviation Administration supervisor is not present he tends to allow himself to become over-extended.

It is real easy for a General Aviation mechanic to allow a customer to talk him into doing things he is not qualified to do. Of course, this customer is the first to leave him when the chips are down and trouble begins. The actual responsibility of limitations is upon the mechanic himself. He should always consider his own knowledge, available technical information, and tools before he accepts any given task.

Perhaps the day is near when people will realize that the human brain can absorb only so much and retain it. When this happens maybe the General Aviation mechanic and the airline mechanic will be separated. Also the mechanic will perhaps have ratings for certain aircraft and aircraft classes. This fact was realized in the certification of pilots many years ago but has not spread to the technical field of the mechanic yet. Stiff opposition to a move similar to this suggestion will be encountered.

The limitation a mechanic places upon himself is the key to the theme of this symposium, "The Man in the Maintenance Reliability System."

AIR AIR CARRIER MECHANIC LOOKS AT THE MAN IN
THE MAINTENANCE RELIABILITY SYSTEM

by

L. Dean Webster
Maintenance Specialist
UNITED AIR LINES

I feel that I can speak as an airline mechanic because I have been one for many years, and although I'm now a part of the management team my role remains in the nuts and bolts phase of the operation.

I believe that if you ask most any carrier mechanic what the term maintenance reliability means to him, you'll find that it means essentially the same as it does to the carrier: safe, efficient, dependable, on-time, and profitable transportation. That's what we're all after.

But the increasing complexity of the aircraft and the fantastic growth of the industry have made achievement of this objective increasingly more difficult -- both for the mechanic and the carrier.

As an outgrowth, the mechanic has certain needs, and I'd like to spend a few minutes discussing them.

First, the need for identification. It is important that the mechanic identify himself within the company. The day is long gone when the mechanic himself, or with a crew chief, could understand and maintain an airplane. It has become necessary to develop what to the mechanic is a complex organization known as maintenance management. For the mechanic who has been at the job long enough to have the "new" worn off, this massive organization can be frustrating. He is apt to develop the attitude that he is little more than a parts changer and a number on a card.

But this doesn't have to be. For the mechanic who will avail himself of the training and advancement opportunities offered by the air carriers today, there is a satisfying career to be had.

Satisfaction may come from recognition. Once the mechanic has identified his position and its responsibility, he may or may not desire to change positions or advance. I recall an individual I worked with when I first started in the air carrier industry. This man had come to us from an engine manufacturer where he assembled cylinders. When I met him he was reconditioning cylinders -- replacing heads, barrels, valve guides and seats, studs, etc. Nearly 20 years later when he retired he was still reconditioning cylinders. His output was so phenomenal that on the day he retired he could bury the man on the downstream side of the assembly line in cylinders. In his advancing years, he had been approached several times with offers of jobs that would be less strenuous, and his reply would turn the air blue. He had identified himself in the company. He had recognition -- and satisfaction from his job. He didn't feel he was just another number on a card He took great pride in the fact he was "the best damn cylinder man" in the industry.

Each mechanic needs to be known and appreciated for the individual he is. Todays jets are so complex, so expensive, and operate at such a high level of performance that everyone dealing with them has to specialize. A mechanic can no longer be a jack-of-all-trades, and his work has to be done in absolute accordance with procedures established by the carrier and the manufacturer. This means that he has to fit into a team and is deprived of certain native independence and individualism.

Strict adherence to work procedures can also have the tendency to lessen the area of his initiative. He may not be entirely free to use his full potential in skills and ingenuity. Every mechanic realizes that within each maintenance and overhaul operation there are many types of jobs, each requiring different amounts of training, each differing in the amount and kind of skill, and each with its own quantity of repetition. Just as each job differs, also each mechanic differs in his ability and personality.

As I see it, the responsibility rests with the supervisor to recognize the capabilities and goals of the mechanics assigned to him, and as nearly as possible place each one in a position where his talents may be best utilized -- where the company will receive the best quality and greatest quantity with the most efficiency.

The degree of control essential in maintenance systems makes it more difficult for the mechanic to recognize discrepancies that are outside his immediate assignment. The fact that discrepancies are not caught by the inspector during his inspection or that a job that needs doing doesn't appear on a job procedure card, doesn't relieve the mechanic of this responsibility. He knows he should

notify his supervisor and get the offending items repaired or replaced. This initiative must be evident in the simplest most routine job as well as in the most complex procedure.

The mechanic needs to know that showing initiative is appreciated and encouraged, and I'm sure that this is a major objective in progressive companies.

Of course, one of the most important needs of a mechanic is the tools to do his job. I've never seen anyone who had all the equipment he would like to have, but on the other hand, from my observation, tooling is an area in industry where the air carriers hold an undisputed lead. There is virtually nothing in the way of newly developed production equipment that is not in use at airline maintenance bases -- assuming it has any worthwhile applications. And many of the most expensive and most advanced items -- electron beam welders, electric discharge machines, automatic testing equipment -- have already paid for themselves after a few months or are expected to once they are installed. Availability of tooling engineers to assist in the design and procurement of special fixtures and other pieces of equipment has helped gain this lead. I believe that mechanics recognize this and are appreciative of the opportunities they have in advancing their knowledge and skills through training on the equipment and using it in their work.

I note that my company is working on improvement of manuals. The objective is to find out what's wrong, if anything, with the present manuals, and from that come up with something better for use with future aircraft. In the past, a mechanic has, at times, had troubles with the interpretation of the maintenance and overhaul manuals as provided by the manufacturers. Also, there were only a certain number of these publications available for use by all the mechanics. Hence, "the little black book" which was generally out of date. This problem has been greatly relieved today through the use of the mechanic's handbook and the written job procedures. These are provided by the combined efforts of the engineers, technicians, and procedure writers. Portions are taken from the manuals, interpreted for use by the mechanics, and placed in the shops in appropriate places. Pocket sized controlled copies of the mechanics handbook are made available in each of the foreman's offices at each line station. This is a great asset in assuring airworthiness and quality of product.

My company is known as the trainingest airline in the business. And this effort goes a long way toward filling the mechanics' need for more and more knowledge. The training facilities and equipment available to a line mechanic are invaluable. They place before him

both in schematic form and, in many instances, actual reproductions of the major electrical, hydraulic, engine, and control systems of the airplane. They make it possible for him, under the direction of qualified training personnel, to assimilate a tremendous amount of working knowledge in a relatively short period of time. And equally important, they make possible periodic update. The shop mechanic has available a training organization whose job it is to provide material pertaining to equipment in current use, and new equipment going into service. The training department also provides study material necessary to prepare the mechanic for advancement. The training and training equipment has to be one of the greatest benefits available to the air carrier mechanic.

I believe the air carriers and mechanics may both look forward to a prosperous and rewarding future, if they willingly accept the responsibility each has to the other, and work together to fulfill their ultimate responsibility which is to the customer.

* * *

CLOSING REMARKS

It was my pleasure to open this symposium on Tuesday morning, and it is now my chore to end it. It has been most gratifying to see the tremendous response, 500 strong, to this year's symposium and to take part in the interchange of information and ideas.

I want to thank all of you who have participated and especially the panelists and panel moderators who have made the sessions meaningful, informative, and worthy of the time spent. Thanks again to those whose offers of papers could not be accepted because of time limitations. As you know, time has been a problem. Thanks also to those who brought the 27 excellent exhibits that are in the next room.

During the past 2½ days, we have heard the views of many segments of the industry about a common concern - The Man In The Maintenance Reliability System. I am pleased to observe that we have not forgotten the man in our maintenance reliability programs.

Our common goal —industry, FAA, and the man in the system — is, and must remain, aviation safety. How well our goal is achieved will depend upon the effort exerted and the cooperation we give to each other.

As a final note, I want to thank all who took the time to attend this fourth annual maintenance symposium. Without your active participation, there would be little exchange of ideas. We hope the trip has been worthwhile.

We have not as yet selected or decided upon a subject for next year's symposium. We want your ideas and suggestions. We do want to continue holding these yearly symposiums that offer a broad coverage and a free exchange of ideas. Several of you have suggested such symposium topics as Automation In Maintenance and "On Condition" Maintenance. Think about it and let us hear from you. We will await your suggestions before we make any decision on next year's symposium subject.

Thank you, gentlemen, for being our guests. This symposium is officially closed.

Have a safe trip home.

Remarks by Harry A. Turnpaugh, Chief, Maintenance Division, Flight Standards Service, Federal Aviation Administration, Department of Transportation.

FAA 1968 Maintenance Symposium
Attendees

INDUSTRY

Alexander, E. W.	LTV
Allegra, Joe	St. Regis Paper Co.
Anderson, L.C.	Westinghouse Electric Co.
Andrews, B. H.	U.S. Steel Corp.
Andrus, Leon	Sonotone Corp.
Arnold, Edward L.	P&W
Bees, Thomas H.	Hydro-Aire Div., Crane Co.
Black, R. K.	R.K. Black, Inc.
Black, William G.	Piper Aircraft Corp.
Blair, E.C.	Westinghouse Electric Co.
Blume, R. H.	Continental Can Co.
Bortniak, Peter	Sperry Flight Systems
Bradshaw, D. D.	Spartan Aviation Inc.
Brindley, Sam	Bell Helicopter Co.
Brinkerhoff, Edgar W.	Tel-Instrument Electronic Corp.
Broadhead, Jean K.	Lockheed (Calif.)
Brooks, Randy	Sinclair Oil Corp.
Broome, B. B.	Spartan Aviation, Inc.
Calvert, C.S.	Aeronca, Inc.
Campbell, Glenn D.	Univac
Campbell, Robert L.	Sikorsky Aircraft
Camplese, Daniel	Lear Siegler, Inc.
Cannon, Charle G.	Cannon Aeronautical Center
Carson, H. L.	Aircraftsmen, Inc.
Cast, Linda Kay	Lear Siegler, Inc.
Clawson, B. W.	Douglas Aircraft
Charlton, A.	Sperry Flight Systems
Conway, Richard	Wilcox Electric Co., Inc.
Damiano, P.A.	General Foods Corp.
Delaney, George	IBM
Dempster, John R.	Sperry Flight Systems
Dodge, John E.	GE
Dougherty, J.W.	National Life & Accident Ins. Co.
Duff, Maurice	Southern Airways Co.
Drake, R. W.	Instruments & Flt. Research
Dunham, L. Wayne	National Distillers & Chemical Corp.
Escott, Fred	Universal Crankshaft
Edwards, Herman C.	Burlington Industries, Inc.
English, Walt	Allison Div. General Motors
Engleson, Howard R.	Aero Data Inc.

Erb, Robert F.	Mtn States Te & Tel
Fischer, Albert E.	Boeing
Forsberg, Philip	GE
Forsgren, Eric	Lockheed
Fredericks, Tom A.	GE
Freeman, Richard L.	Bendix Corp.
Gallagher, Robert W.	I strial Nucleonics Corp.
Garnfo, J. F.	Instrument & Flt. Research
Garrett, Tony L.	KTOK Radio - Okla.
Geick, Gordon	Chandler Evans
Geick, Larry L.	Caterpillar Tractor Co.
Gibbons, G. T.	Douglas Aircraft
Gibson, Coy M.	Allied Bearings Supply, Inc.
Gossett, Marvin H.	Allison Div. General Motors
Grauer, Emerson G.	Wilcox Electric Co., Inc.
Greer, Robert J.	Atlantic Aviation
Gregan, John	Douglas Aircraft
Gregg, William G.	Bendix Corp.
Gregory, Larry S.	Beech Aircraft
Griep, Paul C.	General Motors ATS
Halverson, Elmo	S.C. Johnson
Hamilton, Harold	Hamilton Standard, UAC
Harding, Jim	Cessna Aircraft Co.
Harris, Tom	Management Enterprises, Inc.
Harvey, C. W.	Bethlehem Steel Corp.
Hayes, John L.	Bell Helicopter
Hefner, G. S.	Potters Bros., Inc.
Hinnisey, James E.	LSI Component Ser.
Herbst, William C.	Potters Bros., Inc.
Johnson, Damon B.	Lear Siegler, Inc
Kling, Raymond L.	Cessna Aircraft Co.
Koch, John H.	Koch Training Consultants
Koch, Jean	Koch Training Consultants
Komarek, R. C.	AMCO Engine Co.
Kostick, George	Tel-Instrument Electronic Corp.
Kozak, Henry V.	Bell Helicopter
Kysor, Harley D.	Harley D. Kysor & Assoc.
LaBarre, Floyd Jr.	Curtiss Wright Corp.
Lamb, Charles Richard	Simmonds Precision Products
Lancaster, W.W.	Boeing
Lange, Rolf W.	Potters Bros., Inc.
Larsen, Robert H.	Chandler Evans
LeFevre, William	GE
Lipstein, Martin	Johnson & Johnson
Longlet, Melvin W.	3M Co.

Madaris, R. .	U.S. Steel Acft. Div.
Mayfield, R.	RCA
McAbee, W. H.	Lockheed-Georgia Co.
McCauley, Glenn L.	Federated Dept. Stores
McDonald, E. Graham	Southern Airways, Altanta Ga.
McKeague, Wilt	GE
McKillen, James R.	Bendix Corp.
Menniti, Joseph A.	Grumman Acft. Eng. Corp.
Methven, A. W.	Westinghouse Aerospace Repair
Meyer, Robert E.	P&W
Middlegrook, Victor S.	Aero Data, Inc.
Mitchell, Frank G.	Cessna Aircraft Co.
Mitchell, W. C.	Phillips Petroleum Co.
Moline, Skip	Semco Div. of P.R.C.
Moss, David R.	GE
Mower, Ronald F.	IBM, Flt. Operations
Mutz, Robert E.	P&W
Nall, Jim	Snap-On-Tools Corp.
Novak, W.S.	FMC Corp.
Orendy, Joseph E.	Litton Systems, Inc.
Palmer, E. C.	PSA
Palmer, Grant	P&W
Palmer, Harry A.	Vroman Aviation, Inc.
Penny, Langdon L. Penny	GE
Pinkston, G. E.	RCA
Piper, Ralph E.	Ralph E. Piper & Co. Consultants
Raper, Jim	Lear Siegler, Inc.
Rapson, W. J.	Uson Corp.
Rasmussen, A. R.	Snap-On-Tools Corp.
Riggs, H. B.	General Dynamics/Convair
Rose, Edward A.	Douglas Aircraft
Ruddy, Robert J.	Lear Siegler, Inc.
Rypka, Ed	Litton Guidance & Controls Systems
Sallaway, Charles L.	Cessna Aircraft Co.
Scardino, Nick	Bendix Corp.
Schaum, J. H.	Hercules, Inc.
Scheppler, Robert	Bendix Corp.
Schrader, Ethan A.	Malone Freight Lines, Inc.
Schroeter, Franklin	Forest Oil Corp.
Schwalm, Wayne S.	Southern Airways Co.
Sclafani, Dan A.	General Dynamics
Senia, Joseph W.	Sikorsky Aircraft
Setser, Cheryl	Potters Bros., Inc.
Shannon, Leo J.	Chandler Evans
Shields, Robert V.	General Dynamics/Convair
Sicard, R. L.	Dallas Airmotive, Inc.

Skinner, Bill F.	Flint Steel Corp.
Skinner, James E.	American Aviation Pub., Inc.
Smith, Robert N.	Hamilton Standard, UA
Smoot, Wm S.	Aeronautical Radio, Inc.
Sperling, Paul	Lear Siegler/Astronics
Steinhebell, Lee	Wall Colmonoy Corp.
Stenvers, M. M.	Global Associates
Stephen, Glenn C.	Piper Aircraft Corp.
Storie, Edward L.	Page Aircraft Maint., Inc.
Sutherland, James D.	P&W
Tarker, Charles P.	GE
Templer, Bob	Cessna Aircraft Co.
Tenenbaum, Sol	Aero Data
Terry, Pat	Allied Bearings Supply Co.
Thompson, Neal	United Beech
Thoreson, Leonard J.	Rocketdyne
Unwin, E. P.	Bell Helicopter
Vance, A. Paul	Monsanto Co.
Varner, John N.	Southern Airways of Texas
Viterbo, Patrick J.	Sperry Flt. Systems Div.
Voyles, Larry M.	North American Rockwell Corp.
Wade, Robert C.	Humble Oil & Ref. Co.
Wampler, Len L.	Lear Siegler, Inc.
Watson, Russell W. (Mr. & Mrs)	Cessna Aircraft Co.
Weeg, Melvin	Hydro-Aire
Weiller, Robert E.	Pacific Airmotive Corp.
Weitz, Geo.	George Weitz Associates
Wessel, James A.	Burtek, Inc.
White, Lawrence H.	Chevron Oil Co.
Wilcox, Stephen E.	P&W
Winslow, L. K.	Cessna Aircraft Co.
Winters, Carl S. Dr.	General Motors
Wood, L. G.	General Mills, Inc.
Wood, Robert T.	P&W
Woodrow, David M.	3M Co.
Woods, John K. B.	Boeing
Wright, Ian	Airwork Corp.
Young, Hersey W. Jr.	Cannon Aeronautical Center
Zamoid[illegible], William	Bendix Navigation & Control Div.

U. S. AIR CARRIERS

Antosh, Hank	American Airlines
Ayers, Cicero T.	Piedmont Airlines
Bradley, Charles F.	National Airlines
Clampitt, D. I.	United Air Lines
Dall[illegible], A. W.	Air Transport Assn.
Dobbins, R. W.	Pan Am Airways
Forbes, J.F.	Eastern Air Lines
Fox, Eugene L.	Trans World Airlines
Gardner, Morris R.	Western Air Lines
Gee, William E.	Frontier Airlines
Goldberg, Herbert	Pan American-Business Jets Div.
Graham, Robert J.	American Airlines
Harrison, H.F.	Eastern Airlines
Jones, [illegible]. N.	Continental Air Lines
Judkins, Frank	American Airlines
Kelley, R. P.	Piedmont Aviation
Knight, K. J.	American Airlines
Lambert, Olin W.	Universal Airlines
Manners, Wm.	Pan Am Airways
Morrow, Dan A.	Delta Airlines
McAllister, William L.	Flying Tigers
Nelson, Donald M.	Universal Airlines
Newman, Paul	American Airlines
O'Neill, Laurence S.	United Air Lines
Parkhill, W. W.	United Air Lines
Roney, Emerson H.	American Airlines
Scherer, Richard J.	American Airlines
Stevenson, J. R.	United Air Lines
Tanner, T. J.	Eastern Airlines
Turcott, C. F.	American Airlines
Valenta, Tim B.	Braniff International
Volk, Dick	Western Airlines
Wakehouse, John E.	Western Airlines
Webster, L. D.	United Air Lines
Wonders, Richard R.	Universal Airlines
Zurian, George	Western Airlines

U. S. GOVERNMENT

Ackerman, G. A.	USAF
Adamson, Buddy A.	FAA, OKC
Albin, Spencer K.	Tinker AFB
Alexander, James L.	USAF
Alger, Ron	Tinker AFB
Altman, Charles	Tinker AFB
Anderson, Gordon H.	FAA, Alaska
Ansley, E. L.	Tinker, AFB
Ashby, Robert H.	FAA, OKC
Auchenbach, Paul R.	FAA, OKC
Austin, Jack	Tinker AFB
Bailey, Clyde G.	NASA, Edwards AFB
Baretta, Pat	FAA, OKC
Bass, Kenneth J.	Tinker AFB
Bell, William E.	FAA, OKC
Berry, Gerald G.	FAA, OKC
Biggers, Hope	FAA, OKC
Billingsley, Bob	Tinker AFB
Binion, Thomas H.	FAA, Ft. Worth
Birnbaum, Irving	FAA, Washington, D.C.
Boren, Travis	FAA, OKC
Born, John E.	FAA, Kansas City
Borrego, Salvador	Tinker AFB
Boyle, G. J. Col III	U.S. Army
Brandt, Clinton H.	USAF
Bridges, Robert A.	FAA, OKC
Brown, Don A.	FAA, OKC
Bugg, Robert M.	USAF
Burbick, Robert A.	FAA, Washington, D.C.
Burns, Darla J.	FAA, OKC
Buswell, J.C.	Tinker AFB
Cabrales, G. L.	U.S. Army
Calhoun, Kenneth W.	Tinker AFB
Carr, Paul W.	NASA, Hampton, Va.
Carroll, Russell D.	FAA, Washington, D.C.
Carter, L. P.	Tinker AFB
Cater, William R.	Tinker AFB
Chamers, Gerald B.	FAA, OKC
Chang, John W.	Tinker AFB
Cheuvront, H.R. Capt.	U.S. Navy, NAS Pensacola
Christopher, Jim	FAA, Ft. Worth
Christy, James H.	Tinker AFB
Cline, DeForrest E.	Dept. of Labor, Washington, D.C.
Coffman, Wayne	Tinker AFB
Combs, Robert L.	FAA, OKC
Cooper, William C.	Tinker AFB
Conway, Marvin A.	FAA OKC
Corso, Sam J.	FAA, Washington, D.C.

Covait, Lynne D.	FAA, OKC
Cowroy, Charles E.	FAA, Los Angeles
Crosby, William D.	Tinker AFB
Crosswhite, Betty J.	FAA, OKC
Crothers, Robert K.	FAA, N.Y.
Davidson, Paul E.	Tinker AFB
DeLong, Ray O.	FAA, OKC
Dunsmore, Bob	FAA, OKC
Eckhoff, Charles F.	FAA, Atlantic City
Edmondstone, Geo S.	FAA, Seattle
Edwards, Earl H.	FAA, OKC
Elwell, Arthur W.	FAA, OKC
Enos, Diane	FAA, Washington, D.C.
Estey, Harry D.	FAA, Miami
Faith, R. I	FAA, Washington, D.C.
Falco, Anthony	FAA, N.Y.
Finley, Billy L.	USAF
Flavin, John W.	FAA, Kansas City
Flowers, April	FAA, OKC
Foley, John P. Dr.	Wright-Patterson AFB
Ford, W. D.	FAA, Los Angeles
Francis, David J.	FAA, OKC
Frieburg, R. W.	FAA, OKC
Gesin, Lee R.	Tinker AFB
Gibbon, B. L.	Tinker AFB
Goekler, C. E.	FAA, OKC
Gonzales, Archibaldo	FAA, OKC
Grates, Stanley John	FAA, San Francisco
Green, Beryl B.	FAA, OKC
Hansen, John P. Major	Tinker AFB
Harline, Varney S.	Tinker AFB
Harper, Robert W.	USA
Harvell, H. K.	FAA, OKC
Heinley, Donald	FAA, OKC
Hicks, James W.	FAA, OKC
Hitchcock, Dale L.	FAA, OKC
Holden, James L.	Tinker AFB
Hospy, Joseph	FAA, Honolulu
Hutcherson, Thomas O.	FAA, OKC
Jackson, W. M.	FAA, Washington, D.C.
Jett, G. Lee	FAA, Washington, D.C.
Johann, Orville B.	FAA, OKC
Johnson, Arthur F.	FAA, OKC
Johnson, J. K. Col.	DOD, Pentagon
Johnson, Jack L.	Tinker AFB
Johnson, Richard A.	FAA, Puerto Rico

Juscil, A.	FAA, OKC
Jurick, M. L.	U.S. Navy, Patuxent River
Kincaid, Max	FAA, OKC
Kennedy, Willie	FAA, OKC
Kidman, Delbert	FAA, Los Angeles
Kiefner, John	FAA, N.Y.
Kimbrough, John M.	Tinker AFB
King, W. D.	FAA, OKC
Kirts, Lynn [illegible]	Tinker AFB
Klima, Warren F.	Tinker AFB
Knight, Kenneth C.	Tinker AFB
Knight, Warren [illegible]. 2/Lt.	Tinker AFB
Lane, Lloyd W.	FAA, OKC
Ledden, Roy	FAA, OKC
Levinson, Jerome A.	FAA, Washington, D.C.
Lillie, Edward W.	NTSB, Kansas City
Longman, Chester L.	FAA, OKC
Lockabaugh, Patsy	FAA, OKC
Lutz, George	FAA, OKC
Lutz, Keith W.	Okla. Aeronautics Comm.
Mabry, Harold E.	U.S. Dept. of Agric., Greenbelt, Md.
Manley, Carl H.	Tinker AFB
Manning, J. J.	FAA, OKC
Martin, O.E.	FAA, OKC
Mathews, Claude C.	FAA, OKC
Matthews, Ray	FAA, Miami
Matthews, W. M.	FAA, OKC
May, Francis R.	FAA, OKC
Meehan, John B.	FAA, Ft. Worth
Miller, Larry C.	Tinker AFB
Miraldi, L. J.	FAA, OKC
Mitchell, Louis W.	FAA, OKC
Monschke, Sam R.	FAA, Ft. Worth
Monson, LeRoy G.	FAA, OKC
Morgenstern, Max R.	FAA, OKC
Morris, James L.	FAA, OKC
Mostert, Sue J.	FAA Air Traffic Control; Albany, N.Y.
Moundal[illegible]is, John	FAA, Washington, D.C.
Mueller, Albert L.	FAA, OKC
Muller, Roland A.	FAA, OKC
Mullins, Jerry D.	Tinker AFB
Murphy, Harold D.	FAA, OKC
Murray, William T.	USAF
Myers, Geo.	FAA, OKC
McCain, George D. Jr.	Tinker AFB
McCollough, J. B.	FAA, Washington, D.C.

Neland, Kenneth	FAA, Washington, D.C.
Norrell, James E.	Tinker AFB
Olson, William A.	FAA, Atlanta
Owens, R. A.	FAA, OKC
Page, Harry R. Jr.	Tinker AFB
Pappe, Raymond	Tinker AFB
Parsons, Glyn	FAA, OKC
Patton, Gene M. Col.	Tinker AFB
Pearson, F. R.	U.S. Navy, Patuxent River
Peters, Robert E.	Tinker AFB
Peters, R. T.	FAA, N.Y.
Peterson, Robert S.	FAA, Boston
Plott, Thomasina A.	FAA, OKC
Putt, Harry W.	Tinker AFB
Ramage, James R.	FAA, OKC
Rathburn, Robert E.	FAA, Washington, D.C.
Robinson, L. T.	FAA, OKC
Rohrer, Harley S.	FAA, OKC
Rose, Virgil L.	Tinker AFB
Rowland, Benny F.	FAA, OKC
Sain, Jack A.	FAA, Washington, D.C.
Sala, Kenneth E.	FAA, OKC
Saunders, Vernon W.	NASA, Hampton, Va.
Schenck, Robert J.	FAA, OKC
Schilling, Kurt H.	FAA, Atlantic City
Schueler, James E.	FAA, OKC
Schuermeyer, Harry W.	FAA, Anchorage
Schwager, Frank C.	FAA, Brussels, Belgium
Schwake, Richard O.	Tinker AFB
Seabort, Alice	FAA, OKC
Sebring, H. D.	Tinker AFB
Shaffer, Gene A.	Tinker AFB
Shank, John	Tinker AFB
Shannon, Lowell H.	Tinker AFB
Sheets, C.T.	NTSB, Denver
Shelton, Milton	FAA, OKC
Shepherd, Allen S. Jr.	Tinker AFB
Shepherd, C. B. Jr.	Tinker AFB
Smith, Larry T.	Tinker AFB
Smithhart, Scott	FAA, OKC
Speed, R. G. LCDR.	U. S. Navy, NAS Pensacola
Strloch, Jim	State of Minnesota, St. Paul
Stefany, Wallace C.	CAB, Washington, D.C.
Stevenson, J. H.	FAA, Denver

Strafuss, Herman	Dept. of Army, Ft. Riley
Straubel, Charles E.	FAA, Atlantic City
Sullivan, Roy Lee	FAA, OKC
Supples, Clarence L.	FAA, OKC
Sweeney, Charles H.	FAA, N.Y.
Taylor, Francis J.	FAA, Washington, D.C.
Teasley, Keith	FAA, Washington, D.C.
Thievon, William J.	FAA, Kansas City
Tippett, Floyd S.	Tinker AFB
Turner, Virgil I.	FAA, OKC
Turnpaugh, Harry A.	FAA, Washington, D.C.
Vandiver, Paul H.	Dept. Of Labor, Washington, D.C.
Wall, Gary F.	Tinker AFB
Wernick, Ted	FAA, OKC
White, R. D.	Tinker AFB
Wilcox, Philip M.	FAA, OKC
Wilborn L. D.	FAA, OKC
Williams, Marion W.	FAA, OKC
Williamson, L. H.	FAA, Los Angeles
Williamson, Sharon	FAA, OKC
Wilson, Rhea S.	Tinker AFB
Wright, Harold D.	FAA, OKC
Young, Fred L.	Tinker AFB
Zendler, William T.	FAA, OKC
Zenith, Charles J.	FAA, Los Angeles

UNIONS

Berry, George S.	I.A.M.
Carter, J. M.	I.A.M.
Flood, Frank J. Jr.	I.A.M.
Harris, Lee	I.A.M.
Hatrak, Carl	I.A.M.
Jacobs, James B.	I.A.M.
Latorre, Joe	I.A.M.
O'Connell, Frank	T.W.U.
Stilwell, John E.	I.A.M.

SCHOOLS

Aldrich, Alton P.	Harvard H. Ellis Tech. School
Allen, David	UCLA
Bailey, T. H.	Univ. of Ill.
Bennett, Carl M.	Spartan School of Aero.
Biehler, Fred A.	Oklahoma State Univ.
Birta, Nicholas	Aero. Mech. High School
Bowers, W. K.	UCLA
Broesder, L. H.	Spartan School of Aero.
Carpenter, Don H.	Southeastern State College
Caswell, Charles H.	Embry Riddle Aero. Inst.
Cummings, John	Western Mich. Univ.
Davey, Ralph	Wentworth Inst.
Downey, Thomas J.	Univ. of Ill.
Duncan, William F.	Purdue Univ.
Elliott, Robert T.	UCLA
Evans, Hugh A.	Okla. State Univ.
Fisher, James M.	Pittsburgh Inst. of Aero.
Follmuth, Jim	Minneapolis Voc. School
Gillespie, James	American Flyers
Griffin, John T.	East Coast Aero Tech. School
Harlamert, Ben	Columbus Tech. Inst.
Howe, Leo H.	Parks College
Jones, W. D.	Oklahoma Christian College
Knuckow, Rolland F.	Univ. of Minn.
Kusturs, John J.	Parks College
Lane, Richard	UCLA
Livi, Ivan D.	Pittsburgh Inst. of Aero.
Lyons, Robert E.	Vincennes Univ
Magruder, Owen H. Jr.	Oklahoma State Univ.
Mauro, Kenneth A.	Univ. of Ill.
Murray, Robert F.	National Aviation Academy
Mylin, J. R.	Univ. of Ill.
Olson, Rollie G.	American Flyers
Schaubl., Richard I.	Aero Mechanics School
Shank, Robert R.	Parks College
Smith, Ron	Salina Area Vo-Tech. School
Vai, Anthony	Northrop Inst.

FOREIGN GUESTS

Ankarholt, Olof B.	Swedish Board of Civil Avia.; Stockholm
Berg, D. T.	Dept. of Transport; Onta o, Canada
Bourgoin, John P.	Sud-Aviation; Chicago, Ill.
Delbrail, Jean C.	Sud-Aviation; Paris, France
Dupuis, R. E. Major	Canadian Armed Forces; Ontario, Canada
Edwards, Laurence S.	Air Registrat r Board; Surrey, England
Gallindo, Paulo Lopes	Varig Airlines; N.Y.C., N.Y.
Garton, John E.	British-European Airways; Middlesex, England
Gilchrist, I.	DeHavilland Aircraft; Ontari , Canada
Gomes, J. Tavares	TAP - Portuguese Airways; Lisbon Arpt., Portugal
Gustavsen, Leif E.	DeHavilland Aircraft; Ontario, Canada
Harvey, L. A. Capt.	Canad'an Forces, Tinker AFB
Hulten, Bror Erik	Directorate of Civil Aviation; Copenhagen, Denmark
Hyde, David	BOAC; Burnham, England
Smith, Ian F.	Hawker Siddeley Avivation, Ltd; Syosset, N.Y.
Kilvett, D. C.	Handley Page Ltd.; St. Albans, England
Lay, F. E.	Dept. of Transport; Ottawa, Ontario
Linden, Shamaryahu	El-Al Israel Airlines; Lod Arpt., Israel
Longerna, Philippe	Bureau Veritas; Paris, France
Marchann, J. L.	Air France, Orly Arpt., France
Macooch, Gabriel	ICAO; Montreal, Canada
Masayoshi, Kodera	Japan Air Line; Tokyo Int'l Arpt., Japan
Michel, J. H.	Swissair; Zurich, Switzerland
Nell, Louis A.	South African Airways; Jan Smuts Arpt. Johannesburg, S.A.
Ney, M. W.	Royal Canadian Mounted Police; Ottawa, Canada
Payne, Harry W.	SLAET; Kingston-Upon-Thames, England
Piatkowski, Bogdan	Polish Airlines; Warsawa, Poland
Pickett, Francis	British-European Airways Corp., Surrey, England
Saint-Germain	Sud-Aviation; Toulouse, France
Schmiedt, Otto E. I.	Varig Airlines; N.Y.C., N.Y.
Thatcher, R. J.	Air Canada; Montreal, Canada
Thompson, B. F.	Cathay Pacific Airways; Hong Kong
Tinglum, Per	Directorate of Civil Aviation; Fornebu Arpt. Norway
Treffers, Eba W.	KLM Schiphol Arpt; Amsterdam, Holland
Van Mens, Ernst	KLM Schiphol Arpt, Amsterdam, Holland
Vivian, J. H. LCDR	Canadian Embassy, Washington, D.C.
Wistermayer, Walter	Ministry of Transport; Aviation Dept. Vienna, Austria
Wadislaw, Jannasz	Polish Airlines; Warsaw, Poland
Wramell, Lennart	SAAB Aircraft Co.; Linkoping, Sweden
Zenke, Manfred	Vereinigte Flugtechnische Werke, Bremen, W. Germany